MANUAL COMPETENCE IN CLUMSY CHILDREN

by

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ABSTRACT

This thesis starts by addressing some complex issues concerning the classification of children called 'Clumsy'. The focus then turns more specifically to manual competence in Clumsy children, which is investigated using both a descriptive and an experimental approach. In both cases performance on two different groups of manual tasks is examined: drawing tasks and object manipulation tasks.

Within the descriptive approach, both cross-sectional and longitudinal analyses are undertaken. Firstly, overall differences in the performance between Clumsy children and age-matched controls are described. More detailed examinations are then made of different aspects of movement quality using observation checklists. The main findings are that Clumsy children perform more poorly than controls on simple manual tasks. Their performance is worse, not only in terms of motor control, but also in relation to spatial characteristics and more global factors. It was also found that the movement characteristics of Clumsy children vary at different ages and that, although there are general improvements with age, the motor aspects of performance seem resistant to change.

Within the experimental approach the role of vision in performance is studied in two different ways. Using a correlational approach, one study suggests that although Clumsy children have visual perceptual deficits, it is not clear how these are related to their motor difficulties. Using a different methodology, another study involves the manipulation of visual information to produce different perceptual conditions. The main finding is that Clumsy children (and particularly the younger ones) are affected more by a lack of visual information than controls. It is suggested that the role of vision in Clumsy children may differ at different ages but that generally it seems that they depend heavily on visual information and that they are poor at making sense of kinaesthetic input.

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Chapter One

WHAT IS 'CLUMSY'?

1.1 Introduction

This thesis focuses on problems of manual control in a group of children commonly described as "clumsy". These are children who have problems in the development of movement skills in the absence of any general sensory or intellectual handicap and without overt physical or neurological impairment.

There are three reasons for studying this 'condition'. Firstly, understanding the form that it takes is interesting in its own right. Secondly, since a lack of motor competence is itself distressing and may lead to other educational and adjustment problems, it is important to find ways to help children overcome their motor difficulties. Thirdly, understanding abnormality may contribute to the understanding of normal development.

The case study of Alice presented in table 1.1 illustrates some of the features of this 'condition' (a full version of this case study is provided in Appendix 1). Although this study describes a child at the severe end of the spectrum, her difficulties are by no means unique. Her motor problems were noted early but professionally ignored. She was intelligent, sociable and initially doing well at school which led to further professional neglect. Over time, however, there was a progressive deterioration in motor and other areas. Clearly, there are many reasons for the relative neglect of these children, not the least of which is a lack of resources. However, at a more theoretical level, much of the difficulty centres on problems of classification. The issues surrounding classification of this condition are discussed in the following sections.

Early Infancy: Following a difficult pregnancy and birth, Alice was born at 34 weeks gestation weighing 6lbs 5ozs. As a baby she had difficulties feeding, being unable to suck on a bottle. Her mother also found her hard to dress because she was floppy. She sat late (12 mths) and walked at 18 months but started talking early and spoke in complete sentences by the age of 2 years.

Infant School: When Alice started school she could not climb stairs without pausing with both feet on each step, could not ride a tricycle, use a knife and fork or fasten buttons. However, she could already read and her early progress in number was excellent. At the age of five Alice obtained very poor scores on a test of motor impairment and a neurodevelopmental test. For example, when asked to stand on one leg she was unable to do so for more than two seconds, even with assistance she found it hard to lift one foot off the ground. This meant that she could not jump or hop at all. She also had extreme difficulty with throwing and catching. When a bean bag was thrown towards her it hit her chest before she made any preparatory movement. When asked to return it she simply held it in two hands and released it without any noticeable attempt to propel it.

Her verbal IQ was 121 and at age 5 she was assigned a reading age of 9 yrs 6 mths. Socially, Alice was a popular child. Her verbal facility and sunny personality endeared her to both adults and children.

Junior School: Teachers commented on her coordination difficulties not only in relation to P.E. but also in relation to other types of motor skill (eg handwriting and speech). They noted that she was completely unable to dress or undress.

Academically, she continued to be a conscientious, highly motivated pupil making good progress. Socially she had also made progress. She was popular with her peers, more independent and more mature.

Secondary School: At the age of 16 Alice's extreme clumsiness had not diminished at all. Once again she obtained very poor scores on a test of motor impairment and on a neurodevelopmental test. For example, she could balance on a block for only 4 seconds and jumped little better than she had done at the age of 5. When required to catch a ball in one hand she managed only twice from 10 attempts with her dominant hand and not at all with her other hand. She was also rated as very poor by the P.E. staff in her school and was known to have other kinds of perceptuo-motor difficulties including being unable to find her way around. In other subjects requiring motor competence (eg C.D.T.) she also expended less effort.

On the academic front, Alice had failed to maintain her early success. She seemed to be achieving less, with a lack of effort and interest. In contrast to her earlier social skills, Alice was now socially isolated. She had a low opinion of herself and was very unhappy.

Table 1.1 Case study of Alice (for full version see Appendix 1)

1.2 Terminology

A variety of different terms have been used to refer to children like Alice. Some of these are shown in table 1.2. The large number of different terms used to refer to these children or the 'condition' that they endure is partly explained by the involvement of workers from different professional backgrounds including medicine, psychology, education, and occupational therapy. For example, doctors may use medically oriented terms like "apraxia" (Gubbay, 1978) whereas in education more neutral terms like "movement difficulties" are popular (Sugden and Keogh, 1990). Some terms like "minor neurological dysfunction" refer to the presumed

aetiology of the condition, whereas others refer only to the
movement characteristics themselves (eg physically awkward)
without any reference to what may cause them.

Table 1.2 Terms used by authors to describe the children or
the "condition" they endure.

Term	Author(s)
Clumsy, Developmental Clumsiness	British Medical Journal (1962) Walton, Ellis & Court (1962) Gubbay, Ellis, Walton & Court (1965) Gordon (1969) Dare & Gordon (1970) Gubbay (1975) McKinlay (1978) Keogh, Sugden, Reynard & Calkins (1979) Henderson & Hall (1982) Hulme, Biggerstaff, Moran & McKinlay (1982) Knuckey & Gubbay (1983) Hulme & Lord (1986) Van Dellen & Geuze (1988)
Apraxia, Developmental Apraxia, Developmental Dyspraxia, Dyspraxia-Dysgnosia	Orton (1937) Walton, Ellis & Court (1962) Gubbay (1978) Lesny (1980) Denckla (1984) Cermak (1985)
Physically Awkward	Wall (1982) Wall, Reid & Paton (1990)
Poorly Coordinated	Johnston, Short & Crawford (1987)
Motor Infantilism	Annell (1949)
Delayed Motor Development	Illingworth (1968)
Children with movement difficulties	Henderson, May & Umney (1989) Sugden and Keogh (1990)
Developmental Coordination Disorder	DSM-III-R, (1987)
Minimal Brain Damage	Forsström & von Hofsten (1982)
Minor Neurological Dysfunction	Schellekens, Scholten & Kalverboer (1983) Touwen (1992)
Perceptuo-motor Dysfunction	Laszlo, Bairstow, Rolfe & Bartrip (1988)

In order to avoid confusion and misunderstanding, it is
important that those concerned with children suffering from
this condition agree on a common terminology. Recently, the

condition has received a formal entry in the revised third edition of the American Psychiatric Association's Diagnostic and Statistical Manual (DSM-III-R, 1987) and is called 'Developmental Coordination Disorder'. This is the first time that such an entry has appeared and thus represents a very positive step forward.

Throughout this thesis, however, the term 'Clumsy' is used not only for its brevity and frequent use but also because it has acquired an accepted meaning in the literature and is widely used by clinicians and researchers. Most important perhaps, is that it is neutral with respect to aetiology. As discussed later, our current state of knowledge does not permit us to adopt any term alluding to the aetiology of the condition. On the negative side, however, it is acknowledged that the term 'Clumsy' does have the disadvantage of sometimes being used in a derogatory fashion.

1.3 Classification

In addition to naming a disorder, it is important that those concerned with it agree on a common means of classification. There are three main reasons for classification. Firstly, a differential diagnosis is needed in order to distinguish one condition from others that have similar or overlapping symptomatology. For example, in the case of clumsiness it needs to be distinguished from mental handicap, dyslexia, autism, hyperactivity, cerebral palsy or muscular dystrophy. Only then can the classification be used for epidemiological purposes, to estimate the incidence, nature and distribution of the condition. Secondly, both educational and medical services need to classify Clumsy children in order to be able to allocate resources to them and to prescribe appropriate teaching or therapy. Thirdly, a clear classification is needed to facilitate research. Only by ensuring the uniform identification of subjects can comparisons of different studies be undertaken.

As noted above, the fact that clumsiness receives an entry in DSM-III-R (1987) is in itself a step forward. However, it is clear that much work remains to be done on the entry if it is to become useful in both research and practice. In the following sections the condition outlined in DSM-III-R is exposed to a critical analysis. It is described and enlarged upon in the light of recent research findings and its value examined. Of particular relevance to this thesis is the discussion of issues relating to the assessment and selection of subjects for research purposes. The complete entry for this disorder is reproduced in tables 1.3 and 1.4.

Entry 315.40 Developmental Coordination Disorder

The essential feature of this disorder is a marked impairment in the development of motor coordination that is not explainable by Mental Retardation and that is not due to a known physical disorder. The diagnosis is made only if this impairment significantly interferes with academic achievement or with activities of daily living.

The manifestations of this disorder vary with age and development: young children exhibit clumsiness and delays in developmental milestones (including tying shoelaces, buttoning shirts, and zipping pants); older children display difficulties with the motor aspects of puzzle assembly, model-building, playing ball, and printing or handwriting.

Associated features. Commonly associated problems include delays in other non-motor milestones, Developmental Articulation Disorder, and Developmental Receptive and Expressive Language Disorders.

Age at onset. Recognition of the disorder usually occurs when the child first attempts such tasks as running, holding a knife and fork, or buttoning clothes.

Course. The course is variable. In some cases, lack of coordination continues through adolescence and adulthood.

Prevalence. Prevalence has been estimated to be as high as 6% for children in the age range of 5-11 years.

Differential diagnosis. In specific neurologic disorders that may be associated with problems in coordination (e.g., cerebral palsy, progressive lesions of the cerebellum), there is definite neural damage and abnormal findings on conventional neurologic examination. In **Attention-deficit Hyperactivity Disorder**, there may be falling, bumping into things, or knocking things over because of distractibility and impulsiveness. In **Mental Retardation**, there may be delays in motor milestones, but these are associated with the general impairment in intellectual functioning. Similarly, in Pervasive Developmental Disorders, an abnormal gait and delays in motor milestones are part of a marked and pervasive history of abnormal development.

Table 1.3 DSM-III-R's Classification of Developmental Coordination Disorder (1987 p.48-49)

Diagnostic criteria for 315.40 Developmental Coordination Disorder

A. The person's performance in daily activities requiring motor coordination is markedly below the expected level, given the person's chronological age and intellectual capacity. This may be manifested by marked delays in achieving motor milestones (walking, crawling, sitting), dropping things, "clumsiness", poor performance in sports, or poor handwriting.
B. The disturbance in A significantly interferes with academic achievement or activities of daily living.
C. Not due to a known physical disorder, such as cerebral palsy, hemiplegia, or muscular dystrophy.

Table 1.4 DSM-III-R's Diagnostic Criteria for Developmental Coordination Disorder (1987 p. 49)

DSM-III-R states that:

> "The essential feature of this disorder is marked impairment in the development of motor coordination that is not explainable by Mental Retardation and that is not due to a known physical disorder."

At a superficial level this statement is entirely accurate. However, as soon as one begins to analyze it further, several major questions arise.

1.3.1 Motor Impairment

The first issue which needs to be addressed concerns the phrase "marked impairment in the development of motor coordination". How is this impairment to be defined and measured? The DSM-III-R manual fails to address the many difficulties that are involved in this, including deciding what tasks should be included in an assessment of motor coordination, how performance should be measured and how to differentiate between normal and impaired performance. These and related points are dealt with below.

Deciding what skills to assess:

Firstly motor coordination has to be assessed. In order to do this it is necessary to decide what skills are to be included in the assessment. The DSM-III-R classification includes examples of a few of the functional skills that these children might experience difficulty with. These include tying

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shoelaces, buttoning shirts, model-building, playing ball and handwriting. This list could include a whole range of other fine motor skills such as using scissors, handling coins, catching and throwing a ball and also a variety of gross motor skills such as standing on one leg, running, skipping, hopping, jumping, riding a bike and so on. In addition, more global factors such as the organisation and sequencing of movements could be included.

There are enormous differences in the range or pervasiveness of the problems experienced by different children: some only have difficulty with fine motor skills, others only with gross motor skills and some with all motor skills. Since any single assessment instrument can only focus on a sample of behaviour it would be wise to employ a test of motor competence that includes both fine and gross motor skills. Deciding what skills to select for assessment is difficult because there is no theory of motor development on which to base this selection. There are also other factors, such as cultural differences, that need to be taken into account, as this may influence the relevance of various motor skills. The decision of what skills to select for assessment is an important one and different tests put forward different reasons for their selection.

Choosing age appropriate tasks:
As noted in the DSM-III-R entry, what is considered Clumsy varies with age (see table 1.3). For example, while a ten year old child may be considered Clumsy if he could not throw and catch a tennis ball in one hand or write quickly and legibly, it would not be considered unusual for a four year old to fail these tasks. The younger child may be considered Clumsy, however, if he could not succeed in tasks that most children of the same age find easy, such as catching a bean bag or posting coins in a money box. Thus, once it has been decided what skills to assess, it is necessary to ensure that the tasks employed in the assessment procedure are appropriate for the child's age. For example, when assessing a particular

skill, such as aiming, the tasks may be: for a four year old to roll a ball into a wide goal; for an eight year old to throw a ball into a box and for a twelve year old to throw a ball to hit a small target. While the basic skill being assessed remains the same, the items employed are of increasing difficulty.

Deciding how to measure performance:
Having chosen an appropriate set of tasks to assess the skills of children of different ages, other problems are encountered such as deciding how to measure performance. Some tests of motor competence focus on the outcome or 'product' of movement. For example, they may assess whether or not a child can or cannot button a shirt or catch a ball, how fast a child can run or insert pegs in a board. Other tests attempt the more difficult task of describing 'how' an action is performed, for example the pattern or form of movements involved in attempting to throw a ball (Ulrich, 1985). The latter may be useful in relation to the point made above about age differences, since the form or pattern of movement changes with age. For example, it is quite usual when throwing a ball for a five year old to keep the feet stationary, have no body rotation and only extend the forearm. The same pattern observed in a ten year old would be considered awkward or immature. Also, since the DSM-III-R classification is stated to be for clinical and research purposes, it would not only be useful to know what tasks a child cannot do but also more precisely what difficulties he experiences in attempting those tasks. For example, if a child cannot catch a tennis ball it may be useful to know if this is because he does not watch the ball, does not bring his hands together in time or does not close his fingers around the ball. Only then could one begin to understand the nature of the child's difficulties and plan how to help him learn the skill.

Comparing performance against norms:
Having made a decision as to how to measure performance, it is necessary to then describe the level at which a child can

perform a particular task. This level of performance can be interpreted meaningfully only with respect to established standards or norms. Norms are obtained from a sample which is assumed to be representative of a certain population of subjects and the reliability of the normative data depends upon the adequacy of the sampling procedures. When the sample is representative of the population as a whole, such data provide a basis for judging the performance of any individual in relation to others of his age, sex or other characteristics.

Choosing 'cut off' points:

Having described a child's level of performance in relation to norms, one then has to differentiate between what is normal and impaired performance. The diagnostic criteria for Developmental Coordination Disorder (shown in table 1.4) states that motor coordination must be:

> "markedly below the expected level, given the persons chronological age and intellectual capacity."

Presumably this level would be established by deciding on a cut off point determined from normative data. The only normative data available for these purposes comes from the few standardised tests of motor competence that exist. Where these are used there does not appear to be a general consensus on what cut off points should be used in clinical practice and in research to select Clumsy children. For example, although both van der Meulen et al (1991a) and Geuze and Kalverboer (1987) employed the Test of Motor Impairment (Stott, Moyes and Henderson, 1984), the former selected children for the experimental group if their total scores lay in the bottom 20% of the normal distribution, whereas the latter selected those in the bottom 10%.

If everyone concerned with the classification of Clumsy children came to the same decisions regarding those aspects of assessment discussed above, then there would exist a common language to describe their difficulties. However, that this is not the case in research is reflected in the use of a whole

variety of different assessment procedures. These include reports from parents (Shaw et al., 1982) and teachers (Laszlo, Bairstow, Bartrip and Rolfe, 1988), teacher questionnaires (Shaw et al., 1982; van Dellen and Geuze, 1988), standardized tests of motor function (Henderson and Hall, 1982), a mixture of items from different tests of motor function (Smyth and Glencross, 1986; Lord and Hulme, 1988) and neurodevelopmental examinations (Shaw et al., 1982; Schellekens, Scholten and Kalverboer, 1983; Kalverboer and Brouwer, 1983; Forsström and von Hofsten, 1982). Some studies fail to provide any description of the motor measures employed in subject selection.

Agreement between different measures:
There is much debate about the agreement between different measures of clumsiness. Henderson and Hall (1982) report high agreement between different professional judgements about motor abilities in children of 5-7 years of age. They explain this high agreement by stating that teachers are able to judge young children well, because motor abilities play an important role in scholastic activities at these ages. Other studies, however, report that agreement is generally rather low (Gubbay, 1975; Keogh et al., 1979). For example, Keogh et al. (1979) found a lack of agreement among three identification procedures: a teacher questionnaire, a standard motor test and observation ratings during a P.E. lesson. They suggest that multiple measures should be used for identification purposes.

Determining the consequences of motor impairment:
In addition to the problems involved in assessing motor competence, further criticism of the DSM-III-R entry relates to a statement concerning the consequences of motor impairment. The manual states that:

> "The diagnosis is made only if this impairment significantly interferes with academic achievement or with activities of daily living."

The first point to make is that an impairment in motor coordination should be considered important in its own right,

even if at the time of assessment it is not considered to "interfere" with performance in other areas. One concerning reason for this is that early motor impairment has been found to be associated with a variety of problems in later life, including low academic achievement (Losse et al., 1991).

Secondly, in strict terms it is impossible to determine whether motor impairment "significantly interferes" with other aspects of development since there is no way to measure this relationship. However, this issue often receives subjective comment. For example, a teacher may suspect that the poor handwriting of a Clumsy child is preventing him from displaying the extent of his knowledge in certain subjects. Or a parent may feel that poor manual competence is interfering with their child's ability to dress themselves neatly.

Other suspected consequences of the impairment may not concern "academic achievement or ... activities of daily living" but are nevertheless significant for the child. For example, it is likely that clumsiness will "significantly interfere" with a child's participation in sports and physical education. They may experience a variety of emotional and social problems concerning, for example, fear of failure or not being picked for team games.

Although it is difficult to determine the consequences of clumsiness, this is an important issue and it is suggested that some effort should be made to document the suspected relationship between clumsiness and other problems, even if this can only be done informally.

1.3.2 Intellectual ability

The only information provided in the DSM-III-R manual regarding intellectual ability is that the condition is "not explainable by MR (mental retardation)". All this tells us is that the childrens' difficulties in movement skills cannot be explained by a general low level of intellectual ability.

However, most studies of Clumsy children do provide more comprehensive information on intellectual ability. In many of these studies intelligence has been measured using a short version of the Revised edition of the Weschler Intelligence Scale for Children (WISC-R, Weschler, 1974). This test is designed and organised as a test of general intelligence and yields an intelligence quotient (IQ) with a mean of 100 and a standard deviation of 15. There is a broad agreement between authors that Clumsy children are of at least average intelligence. However, few studies provide individual data for the children. In those that do, it is evident that there is considerable variation. Although there are a few children whose Verbal IQ scores are above 120 and therefore in the "superior" or "very superior" range (Weschler, 1974), the majority of children have scores within what Weschler (1974) calls the "average" range (90-109).

At times the results from IQ tests should be interpreted with caution as they may fail to reflect a child's real intellectual capacity. Children with impaired motor functioning are particularly vulnerable to inaccurate assessment because they often lack the means to display their cognitive ability either motorically or verbally. As outlined in a later section, many Clumsy children have a variety of problems in addition to their movement difficulties. These often include difficulties with speech and language which might affect their performance on the verbal sub-tests. Many also have behavioural and emotional problems which make testing problematic. For example, they may refuse to do an item as directed or be too timid or anxious to perform. With practice and experience the tester will be aware of those factors which may be interfering with the child's performance and will interpret the results accordingly.

1.3.3 Aetiology

The only information provided in the DSM-III-R entry in relation to aetiology is that Developmental Coordination

Disorder is "not due to a known physical disorder". There are however, several factors which may account for a child's clumsiness. These include neurological dysfunction, genetic factors, learning experience and emotional state. The first of these is generally considered to be the most likely cause of clumsiness and is addressed in the most detail. The others have received less attention and are dealt with more briefly.

Neurological Dysfunction :

There is a general belief that the most likely cause of clumsiness is that the childrens' movement difficulties occur as the result of some form of neurological dysfunction. This view is reflected in phrases such as Minimal Neurological Dysfunction (Touwen, 1992) and Minimal Brain Damage (Forsström and von Hofsten, 1982) to describe children with movement difficulties. However, while logically it is clear that adequate motor control generally depends on the integrity of the central nervous system, the precise nature and origin of neurological problems is not clear and a major difficulty lies in obtaining objective evidence of neurological dysfunction.

There are tests which can detect 'hard' (or major) signs of neurological dysfunction (such as severe abnormalities of reflexes, posture or tone) fairly reliably (eg Dubowitz and Dubowitz, 1981). These signs are generally present from birth and are indicative of a definite neurological disorder such as cerebral palsy. Although children who clearly exhibit such signs are excluded from the DSM-III-R classification of Developmental Coordination Disorder (DCD), difficulties arise when children show borderline signs. For example, it is not clear whether children with mild hypotonia should receive the classification of mild cerebral palsy or DCD.

Other tests are designed to assess more subtle deficiencies in neurological function indicated by 'soft' (or minor) signs. For example, such a test may include an assessment of involuntary choreiform or athetoid movements, motor

abnormalities such as mirror movements or difficulty in performing rapid alternating movements (dysdiadochokinesis) and sensory abnormalities such as the inability to identify shapes outlined on the palm of the hand (dysgraphaesthesia) (Touwen, 1979; Stokman et al, 1986).

Rutter (1978) divides these behaviours into three groups. The first includes specific signs which sometimes result from neurological damage but at other times do not. Three examples from this group are nystagmus (in which there is a continual rapid oscillation of the eye-balls) which may be caused by either neurological damage or by labyrinthine disease, the presence of a squint and irrelevant associated movements. The second group includes behaviours which represent slight deviations from normality and which are difficult to detect. These are often mild manifestations of more classic signs which in their unambiguous form would definitely be attributed to neurological damage. Examples from this group include slight asymmetries of tone, marginal hyper- or hypotonia or slightly abnormal reflexes which cannot reliably be detected. The third group of behaviours are signs of developmental delay (for example, poor speech, motor coordination or perception) which can be observed with a high degree of reliability. Such delays may be caused by neurological damage but several other possible explanations also exist (for example, a lack of experience).

The tests used to assess these signs have received much criticism. This has largely been directed at their questionable reliability and validity. Many of the criticisms have been addressed by Touwen and Kalverboer (1973) who outline what they consider to be the essential features of such tests in the older child. They emphasize the importance of age-specific items and standardized recording and elicitation techniques. They also stress that test items should be directly referable to neural mechanisms and that the results should be quantifiable. Unfortunately, these criteria are rarely found in medical practice.

Although neurodevelopmental tests have received much criticism, studies have found some aspects of 'soft' sign assessments to have good reliability in terms of internal consistency, inter-rater agreement etc. (Rutter et al., 1970; Stokman et al., 1986). A number of studies have revealed that Clumsy children do exhibit some 'soft' neurological signs (Henderson and Hall, 1982; Forsström and von Hofsten, 1982; Schellekens et al., 1983; Losse et al., 1991). In addition, research suggests that some signs (eg dysdiadochokinesis, dysgraphaesthesia and motor slowness) are persistent over time (Shafer et al., 1986; Losse et al., 1991). However, what these signs actually mean in terms of neurological structure is certainly not clear.

More recently, there have emerged more direct indices of neurological dysfunction than the behavioural ones. These include the electroencephalogram (EEG) and brain imaging. Gubbay (1975) has provided the most complete descriptions of electroencephalography in clumsiness. He reports that there is evidence that Clumsy children show more EEG abnormalities than control groups but diffuse rather than focal abnormalities predominate and there appears to be no common pattern. Preliminary research attempting to locate sites of brain lesions by brain imaging in Clumsy children has not indicated a specific locus although, in highly selected groups, there has been a relatively high incidence of abnormal CAT (Computer Aided Tomography) scans (Bergstrom and Bille, 1978; Knuckey et al., 1983). For example, Knuckey et al. (1983) found that 39% of their Clumsy group compared to 9% of controls showed anatomical cerebral abnormalities, like ventricular dilation, peripheral atrophy and parenchymal disruption. It is not clear whether or how these structures relate to clumsy behaviour.

Where neurological abnormalities are detected in Clumsy children, little is known about why or how these come about. However, since many authors describe an increased incidence of pre-, peri- or post-natal complications in Clumsy children

(Gubbay et al., 1965; Dare and Gordon, 1970; Morris and Whiting, 1971; Johnston et al., 1987), it has been speculated that neurological dysfunction can occur as a result of anoxia or some other form of birth trauma. Walton et al. (1962) describe a study in which two out of five children were premature births, one had a traumatic delivery following a prolonged labour and one had severe whooping cough at three months. Similarly, Gubbay et al. (1965) report a high incidence of predisposing factors to anoxic birth injury (eg prematurity, forceps delivery) and Henderson and Hall (1982) report a higher incidence of adverse events in the obstetric and medical history of Clumsy children and their mothers compared to controls. There is also evidence that infants who suffered from lack of oxygen and failure of nutrition in the latter part of pregnancy, although less likely to suffer from major handicaps, may display an increase in mild degrees of mental handicap and learning disabilities (eg Drillien, 1972). Similarly, Brown (1980) found evidence for an association between symptomatic neo-natal asphyxia and a variety of handicaps including motor inco-ordination, epilepsy, speech retardation and school problems.

However, there are studies which do not find a higher incidence of such complications in Clumsy children (Iloeje, 1987; Van Dellen et al., 1990). As noted by Taylor (1991), the issue of neonatal hypoxia in full-term infants is very controversial. Taylor reports that research evidence suggests that if a full term infant has no neurological deficit, then birth asphyxia is unlikely to be the cause of any later problem. This suggests that any later neurological dysfunction may already have been present early in gestation.

Finally the complex subject of neurological dysfunction can be related to the 'delay vs deviance' debate. If there is definite evidence of pathology then the child's behaviour may be described as 'deviant' from the norm. However, if there is no evidence of neurological dysfunction then a child's difficulties may be described as 'delayed' motor development.

This notion carries with it the idea that the child will grow out of these difficulties.

Genetic Factors:

Gordon and McKinlay suggest that:

> "Just as there are families with a predisposition to be athletes or musicians there are bound to be families with relatively poor coordination skills."

(Gordon and McKinlay, 1980 p17)

The role of heredity has been implicated by a higher than chance incidence of clumsiness or other developmental disabilities in near relations (Gubbay, 1975). However, it is unlikely that heredity accounts for more than a few cases although there may be some predisposing factors that are inherited.

Learning Experience:

There is no doubt that a child who has had restricted opportunities for play because of poor housing conditions, repeated illness, parental attitudes, lack of toys or nursery class facilities may exhibit poor motor control and coordination. However, like genetic factors, such early deprivation is probably another explanation which accounts for only a minority of cases and after a short period at school, where learning opportunities are increased, performance may improve rapidly.

Emotional State:

Although it is usually impossible to determine whether emotional problems are the cause or effect of motor problems, children do sometimes perform poorly on motor tasks even when they are within their capabilities. For example, they may be anxious or depressed. It seems more likely that an adverse emotional state would exacerbate rather than cause movement difficulties and that this may apply to specific skills like handwriting.

An alternative view to those described above is that clumsiness merely represents the low end of normal variance in motor ability (Hall, 1988). However, Henderson (1986) points out that the proportion of poorly performing individuals seems higher than one would expect if one assumes that such characteristics are normally distributed. There is a secondary hump in the distribution resulting from the presence of individuals who are abnormal in addition to those bottom of the pile on a distribution basis. But unlike reading, there is no statistical evidence for this.

1.3.4 Associated Features

Research has generally shown that the number of Clumsy children with an isolated motor problem is rather small. Far more often problems are also evident in other areas of development (Dare and Gordon, 1970; Henderson and Hall, 1982).

The DSM-II-R manual provides a list of associated features:
> "Commonly associated problems include delays in other non-motor milestones, Developmental Articulation Disorder, and Developmental Receptive and Expressive Language Disorders."

In many ways this list is an odd one. Although Developmental Articulation Disorder is included as an associated feature, it is not entirely non-motor since the articulation of speech sounds does require motor coordination. Also, several of the most common non-motor problems are omitted. These are outlined below. Although it is never easy to establish causal effects, some of these other problems may occur as a result of the childrens' clumsiness.

Learning Difficulties:

Numerous studies attest to the co-occurrence of clumsiness and other learning difficulties in the primary-school years (Nichols and Chen, 1981; Hadders-Algra et al., 1986; Henderson and Hall, 1982; Gordon and McKinlay, 1980; Lyytinen and Ahonen, 1989; Losse et al., 1991). For example, many are poor readers, poor at number work and have poor receptive and

expressive language skills, with some also classified as dyslexic. Several studies indicate a relationship between clumsiness and specific language impairment (Paul et al, 1983; Bishop and Edmundson, 1987; Noterdaeme et al, 1988).

Emotional Problems:

It is often reported that Clumsy children are rather withdrawn and lack self confidence. Lack of self-esteem is a frequently reported characteristic of Clumsy children (Gordon and McKinlay, 1980; Losse et al., 1991). When self concept was divided into different domains, as in the Harter scale (Harter, 1982), Losse et al. (1991) found that Clumsy adolescents had a lower concept of self in the social and physical domains (but not in the cognitive and general domains). For example, they said that they felt as though they were not good at physical activities and that they had no friends. Other emotional problems evident in Clumsy children include insecurity and withdrawal (Kalverboer, 1988) and feelings of anxiety and depression. Some have feelings of frustration when they are unable to perform tasks and consequently begin to exhibit aggressive behaviour. One study has investigated goal-setting behaviour and locus of control in Clumsy children (Henderson, May and Umney, 1989). The findings were that Clumsy children were unrealistic in the way that they set goals for themselves (setting them very high) and were less inclined to accept responsibility for what might happen to them compared to controls. These emotional problems may lead to social problems.

Social Problems:

The social problems experienced by Clumsy children often include having no friends and being rather isolated (Losse et al, 1991; Wall, 1982). It is easy to imagine how a Clumsy child may feel if he lacks the skill to join in when his peers are riding their bikes, playing football or going swimming. At school the Clumsy child may be regarded as slow or stupid when

having difficulty with drawing or writing, in practical classes or in games lessons. Symes (1972) found that Clumsy children are often rejected as a team member during P.E. lessons. At times a child's movement problems may lead to him being picked on or bullied at school. Even at home, the child's relationship with his siblings and parents may be disturbed. The Clumsy child may feel inferior to siblings when unable to do things and parents may find it difficult to cope if the child has problems with eating, washing, dressing etc.. If aspirations of parents for their child are high (as Gubbay, 1975 reports), then the less competent child may not be able to live up to their expectations.

Behavioural Problems:

The social and emotional problems described above may culminate in what are often described as behavioural problems in school. Commonly reported behavioural problems at school are poor concentration and a short attention span (Losse et al., 1991; Lyytinen and Ahonen, 1989). At school some Clumsy children appear quiet, timid and anxious, failing to contribute in class. Others tend to be overactive and at times exhibit boisterous or silly behaviour (Keogh et al., 1979; Kalverboer et al., 1990). Such behaviour can be difficult for a teacher to handle in the classroom, distracting other pupils and demanding individual attention. Gubbay (1975) notes that teachers may view such children as just being naughty and that their movement difficulties may go unrecognised.

1.3.5 Age at onset

The DSM-III-R manual states:

> "Recognition of the disorder usually occurs when the child first attempts such tasks as running, holding a knife and fork, or buttoning clothes."

Although a child's difficulties may become more obvious when he or she attempts these tasks, parents of Clumsy children may recognise their problems right from the start. For example Losse et al. (1991) cite one parent who found her daughter difficult to dress as a baby because she was very floppy (see

31

also the case study in table 1.1). There are two reasons why early signs may go unrecognised. Firstly, there is enormous variation in the level of motor coordination at any age in infancy. Secondly, we lack tests that are subtle enough to detect minor motor difficulties at an early age. It is only when the child reaches the age of five or six years that adequate instruments are available to assess motor competence.

Although there are genuine difficulties in the detection of minor motor impairments at an early age, there are also circumstances in which the formal recognition of an impairment would not be encouraged. This may occur, for example, when the formal recognition or labelling of an impairment is accompanied by an obligation to provide some form of intervention to help the child and if resources are scarce. Whether or not a child's difficulties are formally recognised may also depend upon how their prognosis is viewed. If it is believed that Clumsy children will spontaneously grow out of their difficulties, then any labelling or further action may be considered unnecessary. The course of clumsiness is examined in the next section.

1.3.6 Course
The manual states:

> "The course is variable. In some cases, lack of coordination continues through adolescence and adulthood."

The question of whether clumsiness is a condition which children 'grow out of' without intervention is of considerable importance, both theoretically and practically and there is some research evidence to support this statement in the DSM-III-R manual. This issue is discussed briefly below and a fuller account may be found in the ten year follow-up study of Clumsy children by Losse et al. (1991), a copy of which may be found in Appendix 2.

Some case histories of Clumsy children seem to suggest that a proportion do improve (e.g. Dare and Gordon, 1970; Gubbay,

1975), but close examination of these reveals a number of difficulties, including the fact that these children are often highly selected and may have had intensive therapy.

There are few studies of the course of clumsiness beyond puberty. In one follow-up study of 24 Clumsy teenagers, aged 16 to 20, Knuckey and Gubbay (1983) conclude that their prognosis is generally good, except for the most severely impaired. This should be viewed with some caution for several reasons, including the fact that no information is provided on the motor competence of those lost to follow-up (50% of the original sample).

Gillberg and colleagues carried out a series of follow-up studies in Sweden (Rasmussen et al., 1983; Gillberg et al., 1989; Gillberg and Gillberg, 1989). They identified different groups of children with motor difficulties and found that some children had apparently grown out of their difficulties whereas others had not. One limitation to these studies was that the assessment of motor competence was confined to clinical or laboratory-based tests. Few of these are suitable for teenage children and none have been validated against instruments that have established ecological validity.

In the recent study referred to above, Losse et al. (1991) carried out a ten year follow-up study of 17 children identified as Clumsy at the age of six. They attempted to overcome some of the problems experienced in previous studies by incorporating informal assessments (judgements made by teachers) with a variety of formal ones (including a standardized test of motor competence). The results demonstrated that at the age of 16 these children continued to have substantial motor difficulties, as well as a variety of educational, social and emotional problems. However, there were individual differences in the extent to which the children had learned to cope with their continuing difficulties.

1.3.7 Prevalence

The manual states:

> "Prevalence has been estimated to be as high
> as 6% for children in the age range of 5-11
> years."

As will be evident from the discussion so far, it is difficult to estimate the incidence of this condition. This is due not only to the problems of definition, but also because different decisions have been made in relation to what point clumsiness may be distinguished from low general ability, or from motor impairment which has a diagnosable physical cause. Nevertheless, some attempts to estimate the incidence of clumsiness have been made, producing considerable variance in estimates. In a study by Henderson and Hall (1982) 20 out of a total of 400 five to eight year old children in normal schools were identified as having poor motor coordination for their age, and which was significantly affecting their school work. Henderson and Hall suggest that this indicated "a possibly low estimate of an incidence of around 5%". Other estimates quoted in the literature are 6% (56) of a group of 922 school children in Australia (Gubbay, 1975), and 6.9% (56) of 810 school children aged 8-9 in Britain (Brenner and Gillman, 1966).

1.3.8 Sex ratio

The manual states that no information is available. However, many studies do cite the ratio of males to females who suffer from this condition. A greater incidence of clumsiness in boys than in girls, with a ratio of about 3:1 has been noted in many studies (Reuben and Bakwin, 1968; Keogh et al., 1979; Gordon 1982; Henderson and Hall, 1982; Johnston et al., 1987). This parallels the higher male incidence of other developmental disorders such as hyperactivity (Werry, 1968) and reading difficulties (Critchley, 1970). It has been suggested by Gordon (1982) that this may be related to the slower development of the brain in boys. There is evidence that the more immature the brain, the more it is at risk from acquired damage (Taylor, 1969). However, Gubbay (1975) and

Iloeje (1987) did not find sex differences in their samples of Clumsy children.

1.3.9 Familial pattern

The manual states that there is no information on familial pattern. The role of heredity has been implicated by a higher than chance incidence of clumsiness or other developmental disabilities in near relations (Gubbay, 1975). As yet, however, there is no other evidence to support the notion that clumsiness is hereditary.

1.3.10 Differential diagnosis

Ideally the classification would differentiate between Clumsy children and children with other disorders and also between Clumsy children and normal children. However, in DSM-III-R there is no assumption that each disorder is a discrete entity with sharp boundaries between it and other disorders, or between it and no disorder. The manual does give some information on the differentiation of DCD from other childhood disorders in which there may be some degree of impairment in motor coordination:

> "In **specific neurologic disorders** that may be associated with problems in coordination (eg. cerebral palsy, progressive lesions of the cerebellum), there is definite neural damage and abnormal findings on conventional neurologic examination."
>
> "In **Attention-deficit Hyperactivity Disorder**, there may be falling, bumping into things, or knocking things over because of distractibility and impulsiveness."
>
> "In **Mental Retardation**, there may be delays in motor milestones, but these are associated with the general impairment in intellectual functioning. Similarly, in **Pervasive Developmental Disorders**, an abnormal gait and delays in motor milestones are part of a marked and pervasive history of abnormal development."

There are also other childhood disorders for which some impairment in motor coordination is a feature (including dyslexia and autism). The fact that some Clumsy children are also classified as dyslexic (see section 1.3.4) further

suggests that there is some overlap between clumsiness and other disorders. Clearly the process of separating these disorders presents problems. However, this is not to say that a differential diagnosis cannot be achieved since clearly the determining feature of clumsiness is that motor impairment is the primary feature.

1.4 Individual differences and sub-groups

The DSM-III-R manual refers to individual differences of children with specific developmental delays. It states that:

> "Another misconception is that all people described as having the same mental disorder are alike in all important ways. Although all the people described as having the same mental disorder have at least the defining features of the disorder, they may well differ in other important respects that may affect clinical management and outcome."
>
> (p. xxiii)

Some of these differences have been outlined above and include individual differences in intellectual ability and the range and extent of learning, social and emotional difficulties. However, the manual does not refer to the enormous individual differences in the major defining feature of clumsiness, the movement problems. As outlined above, these may manifest themselves in different ways and may have a variety of different causes. Further research is required in order to determine whether Clumsy children may be grouped purely on the basis of the nature of their motor problems. For example, it may be found that sub-grouping may occur on the basis of whether fine or gross motor skills are effected, or more specifically, according to whether there are visual and/or kinaesthetic processing deficits (Lord and Hulme, 1988; Laszlo et al. (1988).

Some authors have, at a different level of analysis, attempted to identify sub-groups of Clumsy children based on the pattern of behaviour in different areas. For example, within a group of 16 Clumsy children studied at the age of six, Henderson and Hall (1982) identified one group of above average intelligence whose movement difficulties seemed to be an isolated problem.

Another group consisted of those whose movement difficulties were associated with numerous other concomitant problems, their IQ's were at the lower end of the normal range, their general academic attainment was low and their general development appeared to be retarded. Finally there was a third group of children who could not readily be classified in either of these two groups but had a wide range of scores on all of the measures taken.

1.5 Conclusions

In DSM-III-R each of the mental disorders is conceptualized as:

> "a clinically significant behavioral or psychological syndrome or pattern that occurs in a person and that is associated with present distress or disability." (DSM-III-R, p. xxii)

The DSM-III-R classification of 'Developmental Coordination Disorder' includes an outline of the pattern of behaviour that delineates the 'syndrome'. In the present chapter the defining features of this childhood disorder, that we have called Clumsy, have been examined in detail and considered in the light of research findings. This examination has revealed that the defining features or 'symptoms' are formulated in extremely broad terms. Although broad symptom patterns will describe a group, they fail to describe individuals since any one child may show a different pattern. The results from many studies with Clumsy children suggest an association between motor difficulties, emotional, social and learning difficulties and intellectual ability with the relationship between these various factors being too variable for any specific syndrome to be delineated. No information is given in DSM-III-R regarding the heterogeneity of either the childrens' motor or their non-motor difficulties which are so well documented in the research literature.

Although it is vital that the classification of a disorder clearly describes those features that are homogenous, or common to all children suffering from that condition, the

description must not be so broad that it is not useful. At present the DSM-III-R classification of Developmental Coordination Disorder fails to give a clear enough description of the motor problems to allow for decisions to be made regarding what motor skills to assess, how to assess them or how to quantify performance.

It is also important that a classification describes those features that are heterogenous within the group in order to describe individual differences. The DSM-III-R classification fails to give a clear account of the range of difficulties that Clumsy children experience including learning difficulties, emotional and social problems. Without more specific information about the condition, this classification is of little use to either researchers or clinicians.

As noted in this review, there is presently enough knowledge about clumsiness to improve on the DSM-III-R classification. With more research even more specific descriptions of Clumsy children may be obtained. This may occur in two ways. Firstly, deeper levels of analyses may determine more specific commonalities amongst all Clumsy children and may lead to a basis on which they can be classified. Secondly, more distinct sub-groups of Clumsy children may be identified, allowing for more specific classifications to be given.

Chapter Two

MANUAL COMPETENCE IN CLUMSY CHILDREN

2.1 Why study manual competence?

The major focus of this thesis is lack of manual competence in
Clumsy children. Although most children who bear this label
have pervasive difficulties which affect both gross and fine
movements, there is little doubt that poor manual control
affects the child most in terms of progress at home and at
school.

Most children acquire the basic manual skills required in
everyday life without difficulty. By the time they reach
school age they can perform many self help tasks. They can
wash themselves, brush their teeth, brush their hair, put on
a shirt, do up buttons, tie shoelaces, use a knife and fork
and so on. By the same time, they have the skills to
participate in play activities. They can build with lego, fill
containers in the sandpit, hang from a climbing frame etc. In
contrast, many Clumsy children experience real difficulties
with such tasks and may arrive at school unable to put on
their shoes, fasten buttons, build with bricks etc.

In the early school years, tasks requiring the use of the
hands, such as drawing, using scissors and construction are
pervasive throughout the curriculum. Later on, competence in
handwriting becomes an essential prerequisite for progress in
most subjects. In addition, practical classes like science,
cookery and CDT (Craft, Design and Technology) demand manual
competence in tasks such as ruling a line, pouring from a jug
and using a keyboard. In physical education and games lessons
manual competence is necessary for catching and also in bat
and racket control. For many Clumsy children such tasks
represent major obstacles to progress and their inefficient
performance affects them in terms of getting to school on
time, being accepted by their peers, keeping up with school
work, participating in normal activities and so on.

As will become evident in the literature review that follows, the difficulties that Clumsy children experience with the development of fine motor skills has not gone unnoticed. However, in comparison to the apparent severity of the problem, the number of systematic studies that exist is rather small.

2.2 Categorisation of Manual Tasks

The range of tasks that involve the use of the hands is enormous and various approaches have been taken to categorizing them. Some elaborate categorisation systems exist which are based on the underlying structure of the abilities involved such as speed of movement, manual dexterity, finger dexterity etc. (Fleishman, 1975). These abilities have been identified both through task analysis and the statistical procedure of factor analysis.

Other categorisations are based on more obvious or superficial characteristics. For example, tasks may be categorised according to whether or not they have a definite beginning and end, with 'discrete' tasks (eg throwing) at one end of the continuum and 'continuous' tasks (eg tracking) at the other (Schmidt, 1982); or they may be categorised as 'closed' or 'open' according to whether or not the environment is predictable during performance (Poulton, 1957).

More recently, tasks have been categorised into much broader activity systems such as 'graphic', 'constructional' and 'self help' (Keogh and Sugden, 1985); or 'reaching and grasping', 'writing and drawing' and 'keyboarding' (Rosenbaum, 1991).

This approach to categorisation is taken in the present investigations which focus specifically on the manipulative skills of Clumsy children. Within this approach, graphic tasks are almost invariably treated separately from other manual tasks and have frequently been the focus of specific study (Søvik et al., 1987; Wann, 1986). It is partly due to their great educational significance that graphic tasks have

received so much attention.

In addition to graphic tasks, there are many other tasks involving object manipulation that are frequently performed in everyday life (eg handling money, turning a key, unscrewing the lid of a jar etc.). Some may be categorised as self help tasks (for example lacing shoes and buttoning) and have come under specific study (eg Frankenburg & Dodds, 1967; Knobloch & Pasamanick, 1974). Specific aspects of other manipulative tasks, such as squeezing a syringe and unscrewing a nut, have also come under scrutiny (Elliott & Connolly, 1984). However, perhaps due to the varied nature of these tasks, the information available on them is less coherent than that for graphic tasks.

Since the tasks included in the studies that comprise this thesis were specially selected to represent the areas of graphic skills and other fine manipulative skills, this broad distinction is maintained from this point onwards.

2.3 Two approaches to the study of manual competence

Although the division is in no way categorical, a useful distinction can be drawn between two approaches to the study of clumsiness in children. The first, commonly labelled the descriptive approach, is almost self explanatory. In very broad terms, the concern here is with the observation and documentation of movement difficulties. Most of the performance measures focus on the product or outcome of movement (for example time taken to complete an action or the number of successful attempts) and are often interpreted in terms of age related norms. In addition, attempts are sometimes made to provide a description of **how** an action is performed. This may involve verbal descriptions, video recording or very much more sophisticated methods of data collection.

In contrast to the descriptive approach, which tends to be theoretically neutral, the experimental approach is concerned with testing hypotheses about the mechanisms that underlie

movement. The methods employed generally involve laboratory experiments in which crucial variables are manipulated in conditions which are, as far as possible, controlled by the experimenter.

The descriptive approach is in many ways a necessary precursor to any kind of experimental analysis of human performance. Until we can describe the performance difficulties, it is not possible to form useful hypotheses about the mechanisms that might underlie them.

In what follows, the way these two approaches have contributed to our understanding of problems of manual competence in Clumsy children is described. In addition, the shortcomings of each approach are noted and taken up in chapter three where the rationale for the present series of studies is presented.

PART ONE

2.4 THE DESCRIPTIVE APPROACH

Descriptive information on problems of manual control in Clumsy children is available from a number of different sources. Initially, one of the most useful sources of information are parents and teachers. Their reports have the benefit of being based on frequent observation of everyday activities performed by children in natural settings. However, these reports may be subject to bias of various kinds. For example, if parents do not know what is age appropriate behaviour they may wrongly judge their children to be incompetent. On the other hand if they do not want to admit their childrens' difficulties they may overestimate their abilities.

More objective judgements are provided in the case reports of paediatricians and therapists, which are based on their examinations of children in clinical settings (Walton, Ellis

& Court, 1962; Dare & Gordon, 1970). Although these too include informal descriptions of performance, they are often supplemented by the results from formally administered psychometric tests of motor function. In addition to providing norm referenced data, these reports may also include observations relating to the quality of the childrens' movement and the factors that influence it.

Recently, a more systematic source of descriptive information has become available in the form of controlled laboratory investigations. Here, performance data has been collected in a number of ways, varying in technological sophistication. At one end of the spectrum performance of simple pen and paper tasks has been measured using no more than a stop watch and ruler (eg Lord, 1987). At the other extreme, performance on aiming tasks has been measured using optical electronic systems which register XY coordinates of movement from light emitting diodes on the body. From these coordinates, various kinematic characteristics can be determined, including acceleration, deceleration and velocity patterns (Van Dellen & Gueze, 1988; Schellekens et al., 1983).

2.4.1 Graphic Skills

Parents and teachers often note that Clumsy children have difficulty with drawing and writing. Indeed for older Clumsy children, poor handwriting is probably the most salient educational problem. Without skill in this area access to the school curriculum is restricted and many children request the use of a typewriter or word processor as continued failure hinders their progress. Perhaps not surprisingly, therefore, there is a considerable amount of published work which provides descriptive data on Clumsy childrens' difficulties with such tasks. As a starting point, the excerpts from five case studies presented by Walton, Ellis and Court (1962) illustrate the frequency with which the problems are noted (see table 2.1).

Case 1: He seemed quite unable to write, to draw or to copy ... His writing was slow and clumsy with frequent reversals. Case 2: writing was extremely poor ... his drawings of circles, triangles and of a bicycle were extremely crude and ill-formed for a boy of his age. Case 3: his handwriting was crude and the letters ill-formed, while his drawings of a bicycle and a house were extremely elementary. Case 4: his drawing and writing remained extremely poor. Case 5: he could not copy drawings, letters or figures ... His handwriting was crude, showing many reversals and his drawing was extremely poor.

Table 2.1 Excerpts from case studies by Walton, Ellis and Court (1962).
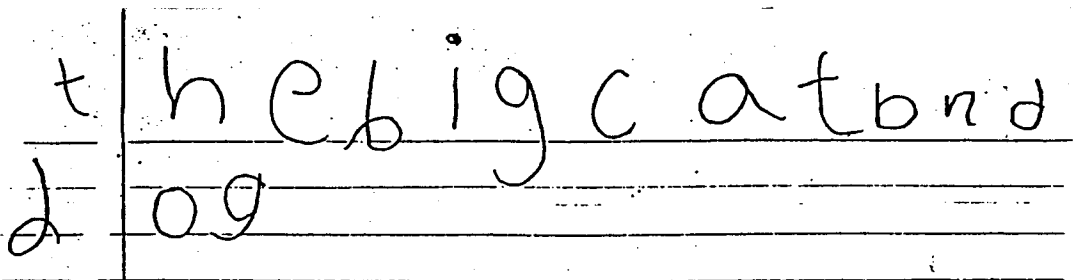
As far as writing is concerned, these problems have been formally recognised and described in varying amounts of detail (O'Hare & Brown, 1989; Søvik, 1984). At the crudest level of analysis, an overall rating of writing quality is used. For example, Lord & Hulme (1988) and Fisher (1990) found that the handwriting of Clumsy children was significantly more untidy than that of control children, as rated by teachers. Some examples are given in figure 2a.

Although lacking a theoretical framework, much more detail is provided in other reports. For example O'Hare and Brown (1989) observe that Clumsy children exhibit the following difficulties: the pen is insecurely held, the writing is shaky, varying pen pressure is applied, there is poor spacing and alignment of letters and words. To these observations, Rubin and Henderson (1982) add problems with letter formation and control of size and slant. Two extremes of speed are also noted. On the one hand writing is at a very slow speed. On the other, a dashing careless speed is observed.

The observation that there are Clumsy children who write particularly slowly has been confirmed in some controlled
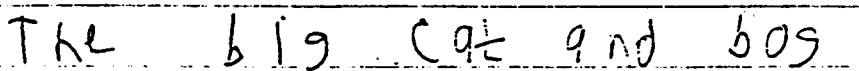
Figure 2a. Handwriting examples from five Clumsy children writing "the big cat and dog". From Fisher (1990).

A
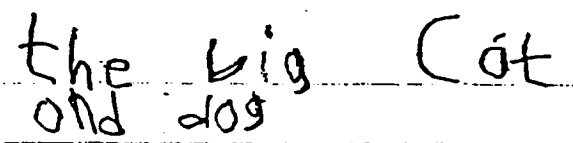
B

C

D

E

studies (Fisher, 1990; Søvik, Arntzen & Thygesen, 1987). However, other studies have failed to find differences between Clumsy and control children in the speed of writing (Rubin and Henderson, 1982; Wann and Jones, 1986; Wann, 1986). These conflicting outcomes may partly be due to variations in writing speed within the Clumsy groups. As noted above, both very slow and very fast writing has been noted in Clumsy children (O'Hare & Brown, 1989) an observation which has been confirmed in more controlled writing studies (Wann, 1986; Wann and Jones, 1986).

Although there is no doubt that the study of poor handwriting in Clumsy children is important, it is also a skill which is difficult to investigate. In addition to motor skill there are many factors which may influence performance (for example, spelling, teaching methods etc.). As an alternative, therefore, some authors have turned to other tasks involving the use of a writing implement. Although few in number, the studies examining difficulties with other graphic skills have employed a useful range of tasks.

In some studies the perceptual demands of the task have been reduced by requiring the child either to draw directly over a line or between two lines. Thus the observed errors reflect more a problem of motor control than of perception. These studies have found that Clumsy children are poor at tracing over various shapes including squares (Lord, 1987), triangles (Lord and Hulme, 1988) and sigmoids (Fisher, 1990). They frequently deviate from the line, there are sudden changes in direction and the drawn line at times looks jerky, as shown by the examples in figure 2b.

Systematic descriptive information is also available on a variety of drawing tasks from some of the psychometric tests used to assess motor performance in Clumsy children. From these it is often evident that Clumsy children fall far behind their peers when norm referenced scoring systems are applied. For example, Schoemaker (1992) found that on the pencil

Figure 2b. Examples of tracing over a sigmoid figure from four Clumsy children. From Fisher (1990).

A

B

C

D
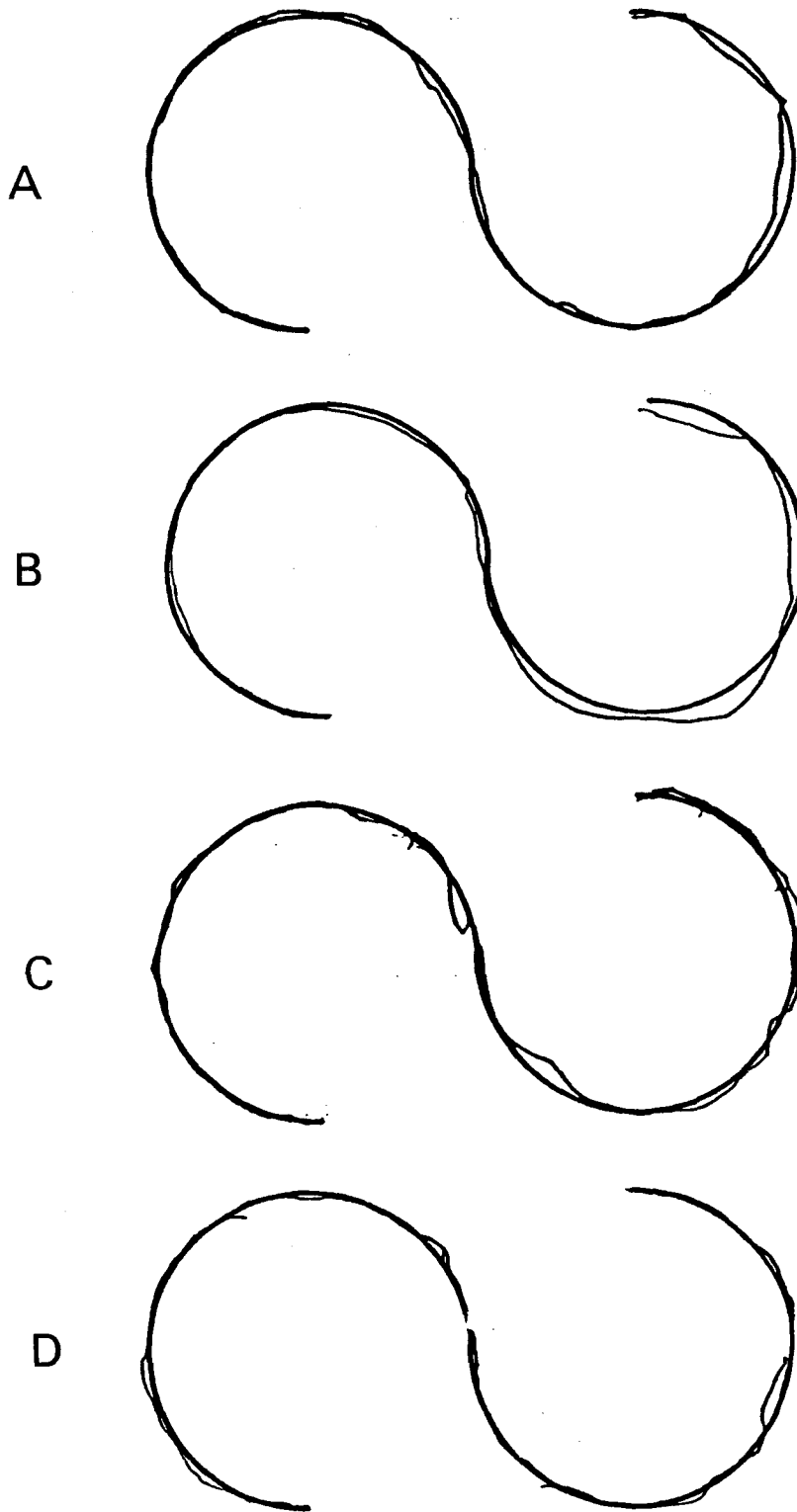
control task in the TOMI, the mean norm scores for the Clumsy children were significantly worse than those for the controls (0.89 and 0.32 respectively).

In other studies, copying tasks have been employed which increase perceptual loading as the child has to look at a stimulus shape then transfer this into movement as he draws. Fisher (1990) found that copying a sigmoid shape proved difficult for Clumsy children. Some examples of their attempts are shown in figure 2c. When required to copy a triangle, Lord and Hulme (1988) found that Clumsy children performed more poorly than controls in terms of the accuracy of shape (or form) but not of the size of their drawings. However, using different shapes (ranging from single straight lines to sigmoids), Hulstijn and Mulder (1986) found that Clumsy children had more errors than controls in all of the aspects studied, including form, size and orientation. They also report that some of the Clumsy children produced drawings in which the stimulus figure was hardly discernable. Schoemaker (1992) found that Clumsy children were less accurate at copying zig-zag figures than controls. She also noted that the Clumsy children looked at the figures more frequently than controls.

In addition to their observations noted above, Hulstijn and Mulder (1986) and Schoemaker (1992) report more detailed information on copying performance obtained by employing sophisticated equipment that digitises the XY coordinates of movement. In Schoemaker's study this has been used to determine a quantitative measure of movement fluency, an aspect of performance that has previously only been recorded qualitatively. She found a tendency for the Clumsy children to draw less fluently, showing more velocity changes, and the group difference increased with more complex figures. The Clumsy children also made longer pauses between strokes than controls.
Both studies employing this technique of movement analysis measured reaction time (RT) separately from movement time

Figure 2c. Examples of shape copying from four Clumsy children (stimulus shape is that shown in figure 2b). From Fisher (1990).

A

B

C

D
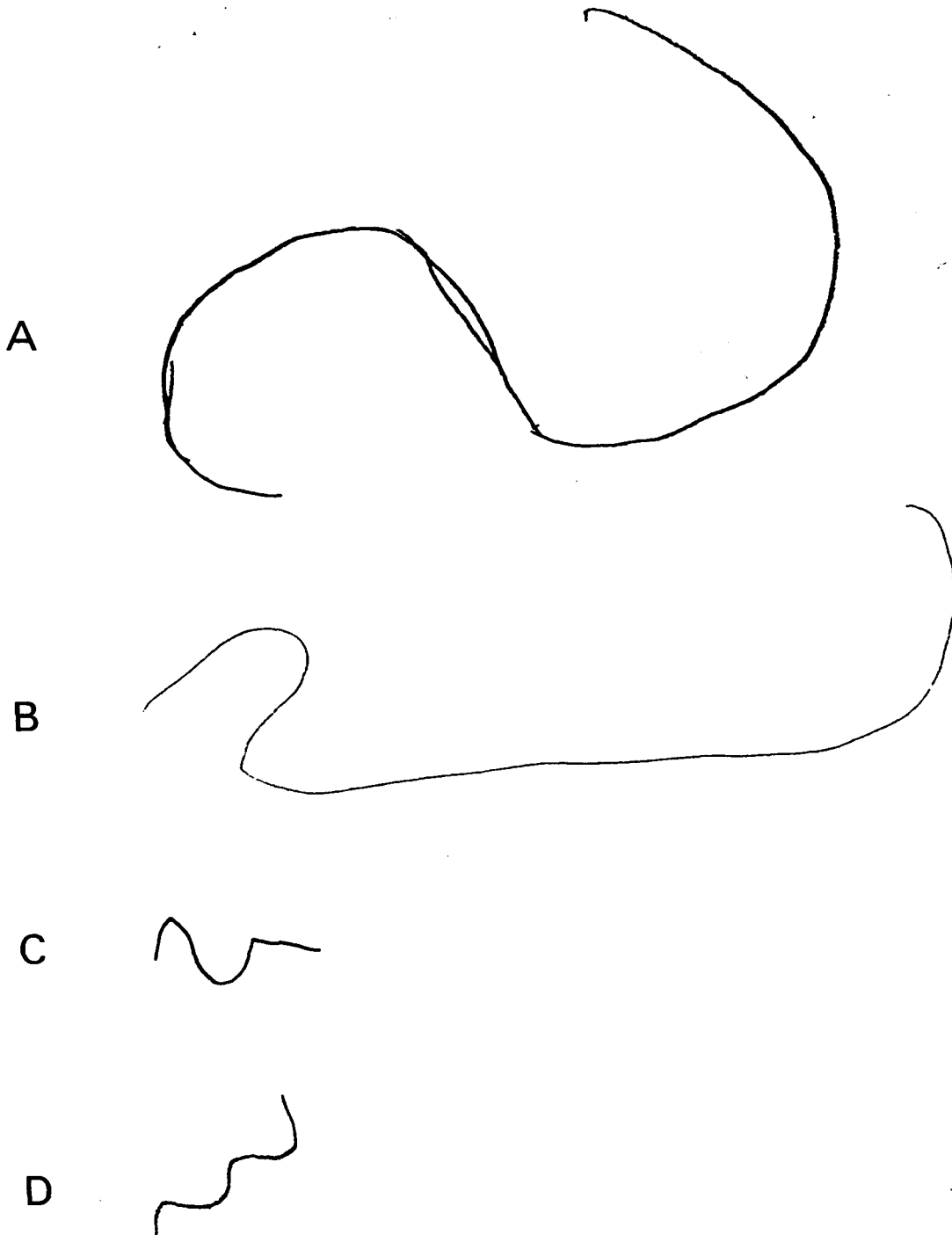
(MT). In terms of RT, Schoemaker (1992) found no significant difference between the groups. Although Hulstijn and Mulder (1986) report longer RT's for Clumsy children, it is not clear whether they instructed the children to move quickly. Both studies found that Clumsy and control children did not differ with respect to movement time. However, Schoemaker found that as the complexity of the figures increased there was a larger difference between the groups in terms of MT (with the Clumsy children performing more slowly).

Lord (1987) also measured speed of performance, without making the distinction between RT and MT. However, his results from the Bishop square drawing task show that Clumsy children performed more quickly than controls. In addition, he found that time taken to complete the task correlated negatively with the number of faults in the Clumsy group only. These contradictory results echo those on handwriting performance discussed above and may similarly be explained by the varying strategies employed by different Clumsy children.

In all of the tasks described above, a stimulus is provided (to be traced or copied) which constrains output. In other drawing tasks, no such constraints are present. Although numerous examples of Clumsy childrens' free drawings are presented in the literature, there are no studies designed specifically to analyze the problems such children have in execution.

Henderson and Hall (1982) employed a drawing task simply as a supplement to a test of motor competence. The children were required to draw a picture with no constraints placed upon them. Focusing on the amount of motor control evident, they reported that the Clumsy group used excessive pressure, showed evidence of tremor and were unable to join lines neatly. The free drawing skills of Clumsy children are examined in more detail in chapter five.

In sum, the performance of Clumsy children has been described on a variety of tasks requiring graphic skill. These include

tracing over figures, copying shapes and handwriting. Most of the descriptive work has focused on movement outcome, providing quantitative information concerning the speed and accuracy of performance. While the performance of Clumsy children is consistently reported to be less accurate, the findings on speed of performance are unequivocal. Some information is also provided on movement quality, for example performance has consistently been described as less fluent and more untidy compared to that of well coordinated control children.

2.4.2 Manipulative Skills

Parents of Clumsy children frequently comment on the problems that their children have with manipulative tasks such as using a knife and fork, fastening buttons etc. These observations are echoed in many case studies (see tables 2.2 and 2.3).

Case 1: he was unable to dress or to feed himself properly ... he could not dress or undress himself without assistance, he could not construct models with blocks, sticks or matches.
Case 2: He was ... unable to use tools ... He was very clumsy in dressing.
Case 3: From early childhood he ... had been regarded as clumsy; he seemed to know what he wanted to do but was unable to make his hands perform the necessary actions... He was unable to construct models.
Case 4: From an early age it had been noticed that the movements of his limbs, and particularly of his hands were extremely clumsy: he was unable to dress himself or to handle a spoon or a knife and fork.

Table 2.2. Excerpts from case studies by Walton, Ellis & Court (1962)

```
Case 1: the obvious clumsiness was highlighted
by such tasks as doing jig-saw puzzles and tying
up shoe-laces.
Case 2: He was very slow in learning to tie his
shoe-laces.
Case 3: he has difficulties in doing up buttons
and shoe-laces.
Case 5: he ... was unable to do up buttons. He
had considerable difficulty in dressing and in
using a knife and fork.
```

Table 2.3. Excerpts from case studies by Dare and Gordon (1970)

As was the case for graphic skills, some descriptive information concerning the performance of Clumsy children on manipulative tasks is available from studies using psychometric tests. For example, using the TOMI, Schoemaker (1992) reports that her group of Clumsy children performed significantly more poorly than controls in manual tasks such as bead threading, peg insertion, ball catching etc. On another test, the ABC (Wiegersma et al, 1988), her Clumsy children also performed significantly more poorly in similar tasks. Moreover, Losse et al. (1991) report that even in the teenage years, Clumsy children perform significantly more poorly than controls when cutting with scissors and catching with one hand.

Although in some respects experimental in nature, there are several controlled laboratory investigations which systematically document problems of manual competence in Clumsy children. Most of these studies have employed aiming tasks with stationary targets, although in one of them the target is moving. Although these tasks do not involve manipulative skill, the studies are worthy of mention because they have employed sophisticated movement analysis techniques which, as noted earlier, provide detailed descriptions of various aspects of speed and accuracy of performance.

In an extensive series of studies by a group of Dutch researchers (eg. Schellekens et al., 1983; Van Dellen, 1987), the performance of Clumsy children has been examined on a task requiring them to aim or point to a stationary target. The action involved in this task is similar to that required in many everyday situations for example, pressing a door bell or turning on the television. Both single aiming movements and repetitive movements between targets have been studied. In general terms the findings are that Clumsy children are slower on all measures taken. They are slower in moving to targets and are slower in terms of "dwell time" on the targets in reciprocal movements. In terms of the detailed analysis of movement quality, the findings were that Clumsy children had a larger average number of movement units per reach (a movement unit consists of one acceleration and one deceleration). One consequence of this was that the proportion of time taken up by the first movement unit was small compared to the controls. Also, the point of maximum acceleration did not consistently appear in the initial unit of movement in Clumsy children and the pattern of acceleration and deceleration within the units was often more irregular.

Using a variation on the task described above, Geuze and Kalverboer (1987) required the children to point repetitively to two targets and examined their ability to alter the pace of movements on command. They found that Clumsy children could not alter their speed successfully, when requested to go slower or faster. Clumsy children found externally paced fast movements most difficult. Although there were some Clumsy children who could manage the task, most were more variable in terms of overall movement time and "dwell time" between movements than their controls.

As noted above, only one study involves a task requiring the children to reach for a moving target (Forsström and von Hofsten, 1982). In this task, a ball moved across the child's line of sight at different speeds and the requirement was to reach and stop it as soon as possible. Forsström and von

Hofsten's findings concerning the microstructure of movements are consistent with those outlined above. They also report that Clumsy children missed the ball more frequently than the controls, especially when it moved faster. In addition, the Clumsy children seemed to take a more devious approach to the target, aiming their movements further ahead of the target than the controls. In an attempt to explain this finding, Forsström and von Hofsten suggest that the Clumsy children might be trying to compensate for their difficulties by adopting this strategy.

Although the studies described so far are certainly relevant to the study of manipulative difficulties in Clumsy children, they are limited in three ways by the nature of the tasks employed. Firstly, the simple pointing tasks are not very appealing to children. Secondly, the spatial aspects of movement are quite severely constrained by the tasks. For example, the beginning and end point of the movement is fixed. Thirdly, none of the tasks involve manipulation of an object using the fingers.

In contrast, a study carried out by Kalverboer and Brouwer (1983) employs a less constrained task that seems more appealing to children and that also involves manipulative skill. In their study they investigate the effect of time pressure and neurological status on performance of a block sorting task. Since this investigation is of particular relevance to the studies to be described in this thesis it will be dealt with in some detail below.

The task employed by Kalverboer and Brouwer required the children to post blocks of different shapes through appropriately shaped holes in a box. In addition to measuring time taken to complete the task, video recordings were made which were later used to describe qualitative aspects of performance. To achieve this a checklist was constructed which consisted of 20 categories describing the most salient aspects of performance. Some examples of the categories are: bimanual

handling (transporting a block with the use of both hands),
misplacement (trying to insert a block in the wrong hole),
forcing (trying to push a block forcefully through a hole) and
associated movements (of the non-active hand or arm).
Kalverboer and Brouwer divided these categories according to
two different frameworks: firstly, by their spatio-temporal
position within the task (eg transportation, insertion) which
is purely descriptive and secondly, by the degree to which
they are thought to reflect aspects of information processing
(ie different selection and decision making processes) which
involves some interpretation in terms of underlying processes.

The study employed three groups of children selected on the
basis of neurological examination results. Differences between
the groups were only found with the girls. Those girls who
performed most poorly on neurological examination and who were
Clumsy, took longer to perform the task, showed a greater lack
of motor control (displaying more minor deviations at
insertion, more arm and trunk movements and more additional
movements), more associated movements and poor task
orientation. Kalverboer and Brouwer suggest that the task may
be less attractive for girls than for boys so that
neurological status interferes with optimal motivation.

In sum, the performance of Clumsy children has been described
on a variety of tasks requiring manipulative skill and
movement outcome is consistently described as slower and less
accurate than that of age matched peers. From the small amount
of work that describes the way in which such tasks are
performed, it is apparent that Clumsy children employ
different strategies, have specific problems of motor control
and are more often distracted from the task compared to their
peers. There are also differences in the microstructure of the
movements of Clumsy children.

2.4.3 Discussion

So far, manual competence of Clumsy children has been
considered at a purely descriptive level. These descriptions

serve several purposes. Firstly, when available as published material they help to raise awareness about clumsiness, by informing people about the condition and the difficulties that these children encounter. Secondly, detailed case studies not only pin point the difficulties experienced by individual children but also identify factors other than motor competence that interfere with performance. This information can be very useful to those who have the task of helping these children to overcome their difficulties. Thirdly and most importantly, these descriptions help to form hypotheses about the possible causes of clumsiness.

Despite the benefits noted above, there are several limitations to the descriptive work. Firstly, many of the descriptions of performance relate to rather constrained tasks (eg tracing and pointing to stationary targets). Although some information is available on tasks that are more relevant to everyday life (such as free drawing and using a knife and fork), much of this has not been collected systematically and lacks detail and coherence.

Secondly, while the main focus has been on descriptions of the product or outcome of Clumsy childrens' movements, there has been relatively little information concerning movement quality or **how** Clumsy children move. Of the available information there are two extremes in the type of data that has been collected, each with its own drawbacks. At one extreme, qualitative information is available that is subjective and unreliable. Some of the case material from parents, teachers and clinicians, for example, includes descriptions of poor grip, tremor and movement described as "clumsy". At the other extreme, attempts have been made to quantify various characteristics of performance using complex movement analysis techniques (eg Schellekens et al., 1983, Schoemaker, 1992).

Thirdly, an overall criticism is that the descriptive work lacks a general framework to guide observation, recording and interpretation of the data. One exception is the study by

Kalverboer and Brouwer (1983) in which an Information
Processing model provides a framework for their observation
checklist. However, their interpretation of the meaning of
observations in terms of information processing is not
entirely clear. An additional problem is that their framework
is specific to the task employed.

Finally, one very important aspect of clumsiness that has
received little attention in the existing studies is the issue
of age effects and how Clumsy children develop over time.

The issues raised in this discussion are taken up again in
chapter three where the rationale for the present series of
studies is described.

PART TWO

2.5 THE EXPERIMENTAL APPROACH

In the study of clumsiness, the experimental approach has been
adopted in attempts to specify a source deficit which might
account for their movement difficulties. This is usually
expressed in information processing terms, a framework
concerned with the way in which sensory information is
processed, stored and used to determine motor activity.

Although attempts have been made to examine different aspects
of information processing in Clumsy children (see Henderson,
1992 or Hulme & Lord, 1986, for reviews), a major focus in
research has been the notion that abnormalities of perceptual
processing constitute the primary deficit. A review of the
work relevant to this debate forms the basis of the following
section.

Analysis of perceptual information

Vision and kinaesthesis are the two major sources of
perceptual information required in the planning and execution

of manual tasks. Vision provides spatial information concerning the position of the hand and other objects as well as information about the form and orientation of objects. Kinaesthesis provides information concerning the position and orientation of the hand and other body parts. In order for movement to be efficient, both of these types of information must be encoded into a common frame of reference. Perhaps not surprisingly, therefore, there are authors who claim to have revealed inadequate functioning of each these perceptual mechanisms. Other studies have attempted to examine the relative contribution of each type of perceptual information in the performance of motor skills. An analysis of these studies and their contribution to our understanding of clumsiness is provided below.

2.5.1 Analysis of Visual Information

Vision provides spatial information to set the scene in which movement will take place. It can also provide temporal information and can be used to monitor movements, especially when precision is required and when there is adequate time for visual information to be processed. Another use of visual information is after the completion of movements in order to observe the effects of an action and determine whether the intended goals have been achieved. Thus visual information helps to specify the environment and to control and evaluate movement.

In part one of this chapter it was noted that Clumsy children experience difficulties with a variety of manual tasks. Many of these place high demands on visuo-spatial processing, for example, writing, copying designs, fitting objects of variable shape into appropriate holes, catching a ball etc.

One particular group of researchers have taken the view that it may be a deficit in visual perception that causes these problems. This line of investigation began in 1982 with a study demonstrating that Clumsy children were less accurate than normal children in both visual and kinaesthetic

perception (Hulme, Biggerstaff, Moran and McKinlay, 1982). The task used required the child to match the length of lines presented either in the same or different modalities. The task was performed under four different conditions: visual-visual (V-V) in which the child looked at a stimulus line for 5 seconds. It was then removed and the child directed the experimenter to extend another line until they judged that it was the same length as the one they had just seen; kinaesthetic-kinaesthetic (K-K) in which vision of the arm was occluded and the child was required to grip a rod and slide it along a slot until it reached a stop. The stop was then removed and the child attempted to produce another movement of exactly the same length; visual-kinaesthetic (V-K) in which the child looked at a line and then tried to reproduce its length by moving a rod and kinaesthetic-visual (K-V) in which the child moved a rod to a stop and then directed the experimenter to extend a line he could see until it appeared to be the same length as the movement just made. The results showed that the Clumsy group were less accurate and more variable in each of these four conditions. However, on the basis of correlations between the children's scores on the perceptual tests and their composite scores on a battery of tests resembling everyday motor tasks, Hulme et al. (1982) argued that the visual deficit is the one that causes clumsiness, since only performance on the task requiring exclusively visual matching correlated significantly with motor performance (see table 2.4).

Recently, Henderson (1992) has noted some features of this study which render this explanation unsatisfactory. Firstly, it was found that the difference between the significant correlation involving V-V matches and the non-significant one involving K-K matches is itself non-significant. Secondly, rather than calculate separate correlations for the Clumsy and control groups, the authors conclusions are based on correlations calculated across both groups together. Thirdly, although the authors concede that the direction of cause and effect cannot be determined simply from correlations, they

continue to use correlational methods.

When attempting to explain the Clumsy childrens' failure on the V-V matching, Hulme et al raised two issues. Firstly, that this may be due to an inability to program eye movements to inspect the straight lines. Secondly it may be due to poor visual memory (since the stimulus line is removed before the child makes a response). These two possible explanations were examined by Hulme, Smart and Moran (1982). They found that Clumsy children had equivalent difficulties with rapid tachistoscopic presentations which precluded the children making eye movements, and also when judging the length of lines presented simultaneously (minimising any memory requirements of the task). It seems, therefore, that the Clumsy children have some very basic problem in coding visually perceived length.

Although it is theoretically reasonable to argue that perceptual impairments might lead to difficulties in developing motor skills, a correlation alone does not establish the direction of cause and effect. There are two other possible explanations for the significant correlation. The first is that it could be the case that abnormalities in motor skills disrupt the development of certain perceptual skills ie. the direction of causality is in the opposite direction. Secondly, the abnormalities may simply coexist, as suggested by Powell and Bishop (1992). In order to try to overcome these sorts of objections, in a subsequent paper Hulme, Smart, Moran and McKinlay (1984) compared the performance of the Clumsy children to a younger group of normal children, whose motor skills were equivalent to those of the Clumsy children, but which were appropriate for their age. If, in this type of comparison, Clumsy children are still worse on a given perceptual task than the controls, then the fact that the two groups have the same level of motor skill shows that the Clumsy children's limited motor skills are not the cause of the problem.

In planning this study, Hulme et al. (1984) found that to match the two groups for motor skill, the normal children had to be more than four years younger than the Clumsy group. They then found that the two groups did not differ on the perceptual measures. This finding is therefore ambiguous with regard to the difficult question of cause and effect. It may be the case that the perceptual problems found amongst these Clumsy children are a result of limited motor skill development; hence when the groups are equated for this, their perceptual skills do not differ. However, it remains possible that the perceptual problems of the Clumsy children are genuinely causally related to their motor problems.

In yet another attempt to show that a deficit in visual perception causes clumsiness, Lord and Hulme (1988) returned to the correlational approach and examined visual discrimination and drawing ability in Clumsy and control children. They found that the two groups differed both on a visual perception task, involving shape discrimination, and on a motor task, involving shape reproduction. This time only those correlations <u>within</u> the groups were calculated and only that in the Clumsy group was found to reach statistical significance, that for the control group was negligible. The authors explain this finding by introducing a threshold notion, asserting that perceptual competence only affects motor ability at the lower end of the scale. Henderson (1992) notes that this argument is post hoc and also points out that it is contradicted by the data in the 1982 study, in which the equivalent correlation between performance in the visual task and motor competence was actually higher for the control group than for the Clumsy group (see table 2.4).

In sum, although there are no reasons to doubt the group results reported, there are several reasons to suggest that the conclusions drawn are problematic, an issue which forms the focus of one of the experiments in this thesis (see chapter five).

Table 2.4. The relationship between performance on two perceptual tasks and two measures of motor competence. Selected data from Hulme et al. (1982) and Lord and Hulme (1988). Reprinted from Henderson (1992).

Mean performance on two perceptual tasks:

Line length matching (AE, 0.1 in)			
Condition	CLUMSY	CONTROL	BOTH
V-V	1.01	0.55	-
K-K	1.17	0.78	-

Shape Discrimination (d prime)			
Condition	CLUMSY	CONTROL	BOTH
V-V	1.19	2.03	-

Correlations between perceptual and motor competence:

Line Matching X Global motor index			
Condition	CLUMSY	CONTROL	BOTH
V-V	-0.34	-0.40	-0.62 **
K-K	-0.13	-0.03	-0.34

Discrimination X Drawing ability			
Condition	CLUMSY	CONTROL	BOTH
V-V	-0.52 *	0.10	-

* $p<.05$
** $p<.01$
- data not reported

2.5.2 Analysis of Kinaesthetic Information

The term 'kinaesthesis' is used to refer to the sense of position and movement of the body and its parts, based on information other than visual, auditory or verbal cues (Howard and Templeton, 1966). Information is gathered through a number of different sensory receptors in the skin, joints, muscles and vestibular apparatus, which contribute to the global perception of kinaesthesis.

The role of kinaesthesis in movement has been studied indirectly in deafferentation studies in animals (Taub, 1976) and man (Rothwell et al., 1982) which have shown that kinaesthesis is involved in the fine tuning of skilled movement. Kinaesthesis has also been considered to play a role in the learning and performance of motor tasks, although its exact contribution is unclear (Henry, 1953; Elliott et al., 1988). Laszlo and Bairstow (1985) have argued that kinaesthesis is important in the learning and performance of all skilled motor acts. They also propose that those less able in motor skills may have kinaesthetic perceptual deficits. In

order to facilitate the separation of kinaesthetic function
from motor function they developed a Kinaesthetic Sensitivity
Test (KST) (Laszlo and Bairstow, 1985). This test has two
formally published components: one, designed to test
kinaesthetic acuity, requires the subject to sense the
location of his arms (without being able to see them) after
they have been passively positioned, judging which is the
higher. The other, designed as a test of kinaesthetic
perception and memory, is a cross-modal task. The subject's
hand is guided round a complex shape, without him being able
to see it. The experimenter then changes the orientation of
the shape and presents it to the subject visually. The task is
to restore it to the original, kinaesthetically explored
orientation.

The authors provide normative data for children of different
ages and for adults on these two tasks (Laszlo and Bairstow,
1983). In their 1981 paper they simply report that "eight out
of the 14 clumsy children tested showed a marked inability to
process kinaesthetic information: they could be labelled
'kinaesthetically blind'". Unfortunately no details of these
childrens' performance are given, nor of how they were
identified as Clumsy. However, in a later study, Laszlo and
Bairstow (1985) provide more detail on the performance of a
group of 16 Clumsy children, aged between 7 and 15, who had
been referred to paediatricians for assessment because of
motor difficulties. Seventy percent of these children were
reported to have performed below the 25th percentile for their
age on the kinaesthetic acuity task and for the kinaesthetic
perception and memory task, half performed below this level.

On the basis of their findings, Laszlo and Bairstow (1985)
claim that many Clumsy children perform below average on the
Kinaesthetic Sensitivity Test and that the "test enables
diagnosis of the specific difficulty". They also claim that
performance on the KST correlates significantly with
performance on a broadly based test of motor competence, the
TOMI (Laszlo et al., 1988) and a writing task (Bairstow and

Laszlo, 1981).

Recently, however, a number of studies have challenged both the incidence figures of Clumsy children reported to perform poorly on the test and the correlational data provided by Laszlo and Bairstow. When Lord and Hulme (1987) compared the performance of Clumsy and control children on the KST they found that the two groups did not differ significantly on either task. Also, Hoare and Larkin (1991) employed the KST alongside other tasks in a general study of kinaesthesis in Clumsy children. Although they found that the Clumsy group performed significantly less accurately on the acuity task than controls, only 24% of the Clumsy children performed below the 25th percentile. The perception and memory task did not separate the groups, with only 28% of the Clumsy children performing below the 25th percentile, which was only slightly more than the control group (20%).

With regard to the correlational data presented by Laszlo and Bairstow, other studies have reported data which is inconsistent with these findings (Sugden and Wann, 1987; Elliott, Connolly and Doyle, 1988). For example, Elliott et al. (1988) found no evidence for an association between kinaesthetic acuity and motor performance on a range of motor tests. When Lord and Hulme (1987) examined the relationship of kinaesthesis to measures of motor performance, the correlational evidence they obtained was ambiguous. Three out of eight correlations were significant in the Clumsy group (all involving the kinaesthetic acuity task) and 2 out of 8 were significant in the control group (all involving the kinaesthetic perception and memory task).

Doubts about the psychometric properties of the KST were first raised by Doyle, Elliott and Connolly in 1986. Their concern related to the procedure used for the angle discrimination task during the development of the KST. However, Laszlo and Bairstow (1986) retorted that these criticisms were not appropriate to the modified version of the test. Lord and

Hulme (1987) have further criticised the test, reporting that insufficient attention has been paid to it's reliability and validity. For example, they note that reliability for some age groups is unacceptably low, the practical consequences of which are that score variance will reflect a high proportion of error variance. Noting that test length and item difficulty affect reliability, they also report that the acuity task is too difficult for most children under 12, thus many may simply respond randomly. Finally they note the difficulty in interpreting performance on the perception and memory task. This complex task involves kinaesthetic perception, cross modal transfer, visual perception and memory.

In spite of a continuing debate about the psychometric integrity of the KST (Doyle, Elliott and Connolly, 1986), Laszlo and Bairstow pursued their hypothesis that clumsiness is caused by a kinaesthetic deficit by carrying out an intervention study (Laszlo, Bairstow, Bartrip and Rolfe, 1988). The forty children who participated in the study were selected by their teachers as Clumsy and confirmed to be so on a standardised test of general motor competence (the TOMI). The children were also assessed on the Perceptual-Motor Abilities Test (PMAT, Laszlo and Bairstow, 1985) which, the authors claim, identifies deficits in specific processes. The Clumsy children were allocated to four different groups and each received a different kind of intervention: the first were trained on all processes found to be deficient, using the items from the PMAT, which includes the KST; the second were trained on the KST only; the third were trained on spatial and/or temporal tasks from the PMAT; the fourth were trained on more task oriented fine and gross motor skills. Allocation to group was done on a random basis except that all of the children allocated to groups two and three had been identified as having kinaesthetic deficits and spatial and/or temporal deficits. When general motor competence was tested again at the end of treatment, the results showed that those children in groups one and two improved dramatically on the TOMI. Those in groups three and four did not improve significantly. The

study also incorporated a cross over design whereby those children in groups three and four had further intervention. This time, group three were trained on the KST and group four on all processes in which they were found to be deficient (including the KST). Both groups were found to improve significantly after this second phase of intervention.

Schoemaker (1992) suggests that the results of the study need further elaboration, for example in terms of the size of the transfer effect to other tasks (ie. those in the TOMI). Even so, the results are quite remarkable in several ways. Firstly, as Henderson (1992) notes, this is one of the few intervention studies which has been able to demonstrate measurable effects on impaired children's motor performance. Secondly, the intervention only lasted two to three hours and finally, the children who were given only the rather passive kinaesthetic training did better than others who were trained on activities which seemed more similar to the TOMI test items. Those who were trained on the two components of the KST improved dramatically on the TOMI. Those who received other kinds of intervention did not.

At a theoretical level, intervention studies are important in aiding the identification of causes of developmental abnormalities. If, as in Laszlo et al's study, it can be found that Clumsy children have specific processing deficits and that training can improve both the deficits and their motor skills, then this is good evidence that the processing deficit is, at least partly, the cause of the motor problems.

With such intervention studies it is important that the processing deficit can be conceptualised and measured. In a recent study, Hoare and Larkin (1991) considered whether kinaesthesis may be considered as a single concept by examining the relationships between seven different kinaesthetic tasks (the two KST tasks, K-K, K-V and V-K line-length matching, linear positioning and weight discrimination). They found only limited relationships between

the tasks and report that they appear to be measuring a number of different aspects of kinaesthesis. They conclude that kinaesthesis can only be conceptualised as a global, multi-modal construct. In terms of measurement, the practical consequence of this is that kinaesthesis is difficult to measure. In addition to the earlier criticisms of the KST, it is clear that kinaesthesis is too complex to be measured by only two tasks.

In sum, there is some evidence to suggest that Clumsy children have deficits in the processing of visual and kinaesthetic information. However, little is known about how these relate to performance on motor tasks.

2.4.3 The Role of Vision and Kinaesthesis in Movement:

To this point, visual and kinaesthetic perception in Clumsy children have been discussed separately. This separation, however, is rather artificial since they are both important for the planning and execution of movement and in many ways operate together.

In the case of visual perceptual problems, the studies with Clumsy children have involved investigations of purely visual tasks. Since our main concern is difficulties of movement it is more appropriate to examine the perceptual problems within a movement context.

This section of the review focuses on a small number of studies that have employed a methodology that allows for an investigation of the role of vision and kinaesthesis in Clumsy children within a movement context. The method involves examining the effect of removing vision on performance.

These studies can broadly be divided into two groups according to the point at which the availability of vision was manipulated. In some it was manipulated at the input stage, while in others, vision at output was manipulated.

Four studies have manipulated vision at the input stage, two employing a task requiring children to match the length of lines by moving a handle along a constrained pathway (Hulme et al, 1982; Hoare and Larkin, 1992) and two involving pointing to a target (von Hofsten and Rösblad, 1992; Jongmans, 1989).

The line-length matching task has already been described in section 2.4.1 above with specific reference to the visual perceptual abilities of Clumsy children (Hulme et al., 1982). By focusing only on those conditions that require a manual response (the V-K and K-K conditions) it is possible to examine the contribution of kinaesthesis and vision to the planning and control of simple arm movements. As noted above, in the V-K condition vision of the arm was occluded and the child viewed a stimulus line for 5 seconds. This was then removed and the child pushed the rod along the slot to produce a movement of the same length as the line just seen. In the K-K condition vision of the arm was occluded and the child was required to grip a rod and slide it along a slot until it reached a stop. The stop was then removed and the child attempted to produce another movement of exactly the same length. Thus, vision was manipulated at the input stage so that the stimulus was either seen or felt prior to the response. As part of their extensive study on kinaesthesis in Clumsy children, Hoare and Larkin (1991) employed exactly the same procedure. The results of these two studies are plotted in figure 2d.

As shown, both studies found that the Clumsy children performed more poorly than controls in terms of the accuracy of matching on both conditions. Cross-modal performance seemed to be worse than intra-modal performance. A statistical analysis of this data by Lord and Hulme found that the difference between the two conditions was highly significant (p<.001). The group difference was significant across both conditions, with Clumsy children performing more poorly than controls, with no interaction between group and condition. Unfortunately, Hoare and Larkin (1991) analyze their results

Hulme et al. (1982)

Absolute Error (0.1in.)
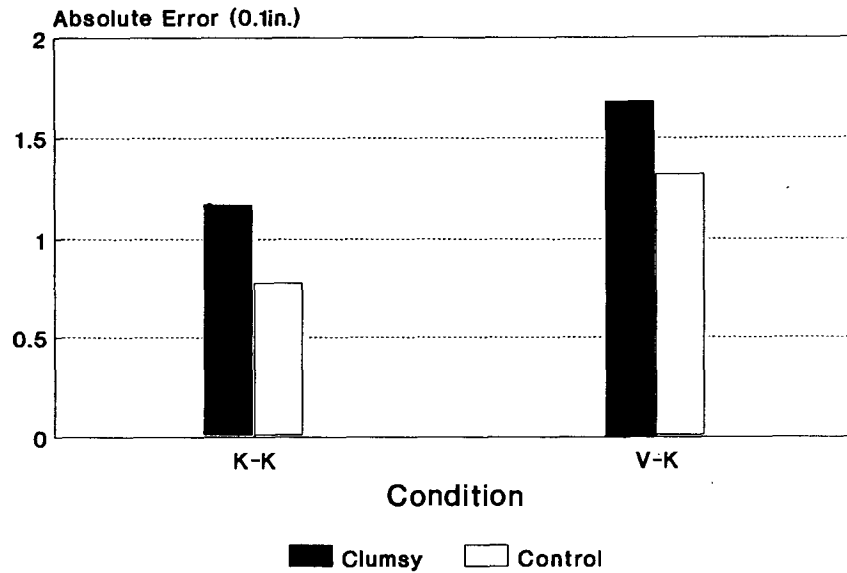
Line-Length Matching

Hoare & Larkin (1991)
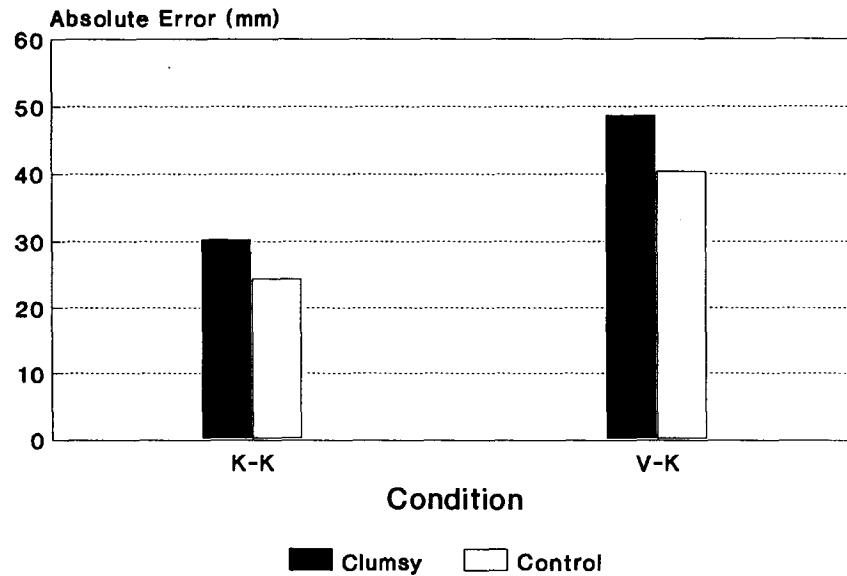
Absolute Error (mm)

Line-Length Matching

Figure 2d. Absolute errors for line-length matching task with Clumsy and control children. Upper: Replotted from Hulme et al. (1982). Lower: Replotted from Hoare and Larkin (1991).

differently and do not examine the effect of condition. However, examining the conditions separately, they found that in the V-K task the group difference approached significance at p=0.02 but in the K-K task it did not.

Other studies manipulating vision at input have employed a target localisation task originally devised by von Hofsten and Rösblad (1988). The task involved reaching under a table to position a pin or magnet underneath a dot located on the table top. Reaching for the target was always guided kinaesthetically (the reaching arm was not visible) but the task was varied according to the type of perceptual information that was simultaneously available to locate the target on the table top. In a V-K condition the dot was seen only, in a VK-K condition the dot was seen and felt with the finger of one hand and in a K-K condition the dot was felt only (vision was occluded).

Von Hofsten and Rösblad (1988) first employed this task in a study with 270 normal children and found a stable pattern across a 5 to 12 year age band with the absence of vision having the most marked effect on performance. These findings are generally confirmed by the results from normal children in other studies (eg Jongmans, 1989).

Of particular relevance to the present discussion are two other studies that have employed the same pointing task. The first, carried out by von Hofsten and Rösblad (1992), studied a heterogenous group of motor impaired children (with cerebral palsy, Clumsiness and spina bifida). The second, carried out by Jongmans (1989), studied Clumsy children only. The results from both studies are shown in figure 2e.

The results from the two studies are comparable. However, as with the studies described earlier, they analysed their data rather differently. From the figure it can be seen that motor impaired children performed more poorly than controls in terms of pointing errors (von Hofsten and Rösblad found no

von Hofsten & Rosblad (1988 & 1992)
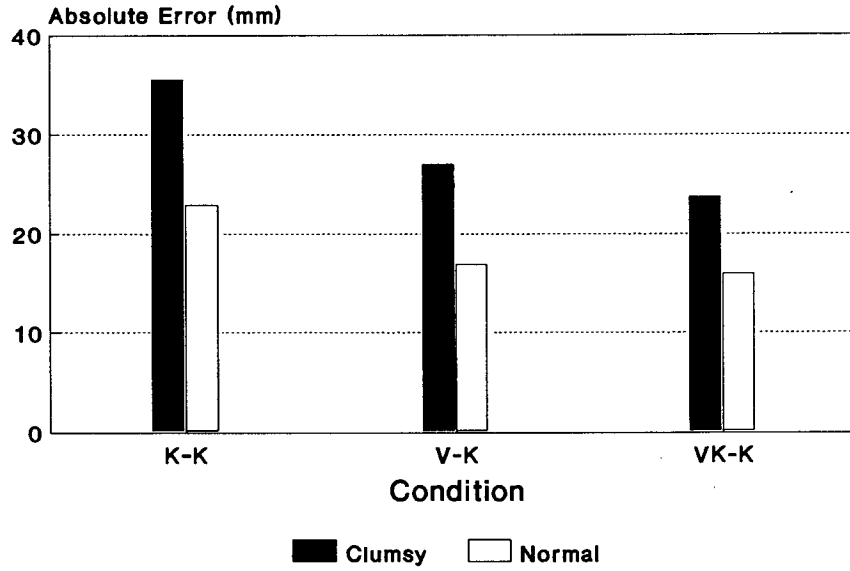
Absolute Error (mm)

Pointing to Target

Jongmans (1989)
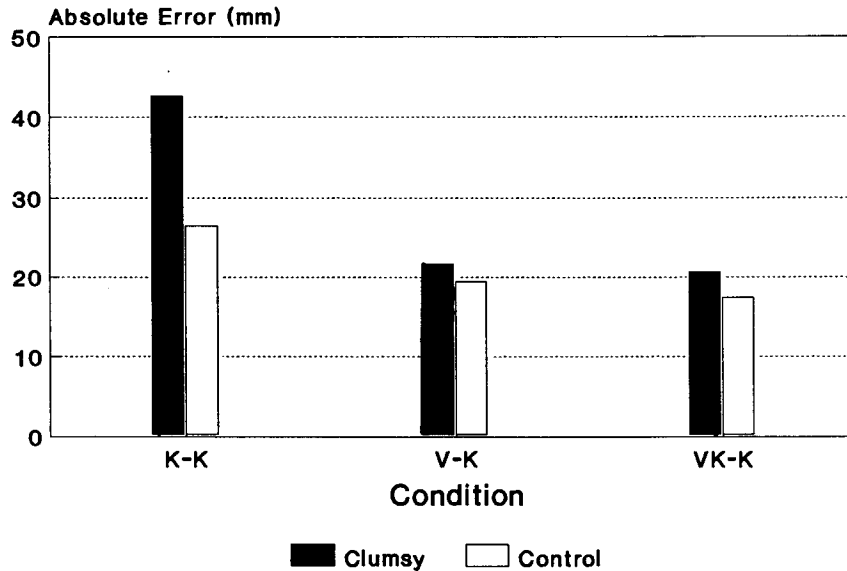
Absolute Error (mm)

Pointing to Target

Figure 2e. Absolute errors for pointing task with Clumsy and control children. Upper: Replotted from von Hofsten and Rosblad (1988 and 1992). Lower: Replotted from Jongmans

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significant differences between the three groups of motor impaired children). Performance was best when both vision and kinaesthesis were available and worst when only kinaesthesis was available to specify the target position. A statistical analysis of the data by Jongmans (1989) found that performance in the K-K condition was significantly worse than that in both of the other conditions but that there was no significant difference between performance on the V-K and VK-K conditions. In terms of differences between the two groups of children, this was only significant in the K-K condition. Thus, the interaction between group and condition was significant (p<.001). Unfortunately, von Hofsten and Rösblad (1992) did not examine the effect of condition. However, in examining the conditions separately, they found that the group difference was highly significant in the K-K condition (p_{min}<.01) but when vision was available, the differences between the groups were less clear (in the V-K condition the difference was only significant for the dominant hand, in the VK-K condition it was only significant for the non-dominant hand).

At first sight, these two series of studies, employing line length matching and pointing tasks, appear to produce conflicting results. The first suggest that children have more difficulty under cross-modal conditions when translating visual information into a movement, while the second suggests that children have more difficulty under intra-modal conditions when translating kinaesthetic information into a movement. However, since each pattern of results has been obtained in more than one study and is true for both normal and Clumsy children, the conflicting results probably say more about task differences than anything else. For example if we focus on the K-K conditions of the line-length matching and the pointing task, the following differences are apparent. In the former the stimulus is actively sampled (the child moves the handle along the rail to a stop), the stimulus is identical to the required response and they occur successively. In the latter the stimulus may be passive or partly active (the child's finger is placed on a dot by the

experimenter), the stimulus and response are quite different in nature and the stimulus is present throughout performance. As Wann (1991) points out, since the stimulus is simultaneously available in the pointing task, this provides a more direct measure of visual-kinaesthetic mapping. However, in the K-K (or intra modal) condition of the pointing task the child is not required to directly match the orientation of one limb to another. Rather, asymmetrical movements are required (with one hand above the table and the other below it). Wann notes that this procedure does not allow one to differentiate between specific sensory problems and the problem of encoding visual and kinaesthetic spatial cues within a common egocentric frame of reference.

Another important difference to note between the tasks is that the line-length matching task is confounded by a short term memory requirement. When a memory component was included within the von Hofsten and Rösblad studies it was found to markedly increase error rates. In their memory condition (MV-K) the difference between normal and motor impaired children was significant. Although they do not report interaction effects, when the data is plotted as in figure 2f, there is some suggestion that memory may have a differential effect for the normal and motor impaired groups. Unfortunately von Hofsten and Rösblad only introduced the memory component to the V-K condition (the child was to look at the dot, memorize its position, then close the eyes and locate the target underneath the table). Thus we cannot rule out the possibility that memory has a differential effect, not only on the normal and Clumsy children but also on the K-K and V-K conditions, resulting in considerably poorer cross-modal performance. This would explain Hoare and Larkin's findings that Clumsy children performed significantly more poorly than controls only in the V-K condition.

There are several possible explanations for the sensitivity of the Clumsy group to the withdrawal of visual information. These relate to the variety of roles that vision may have in

von Hofsten & Rosblad (1992)

Absolute Error (mm)

Condition: V-K, MV-K

■ Clumsy □ Normal

Pointing to Target
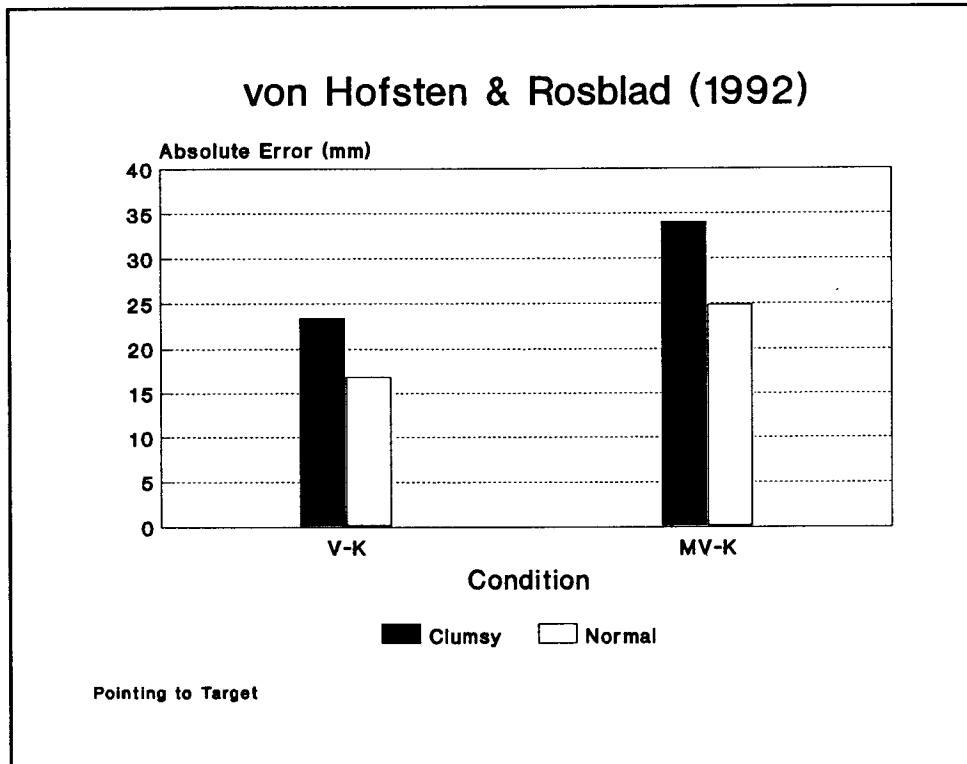
Figure 2f. Absolute errors for pointing task with Clumsy (n=11) and normal (n=270) children.

Lord & Hulme (1988)

Absolute Error (mm)

Condition: V-K, V-VK

■ Clumsy □ Control

Shape Copying
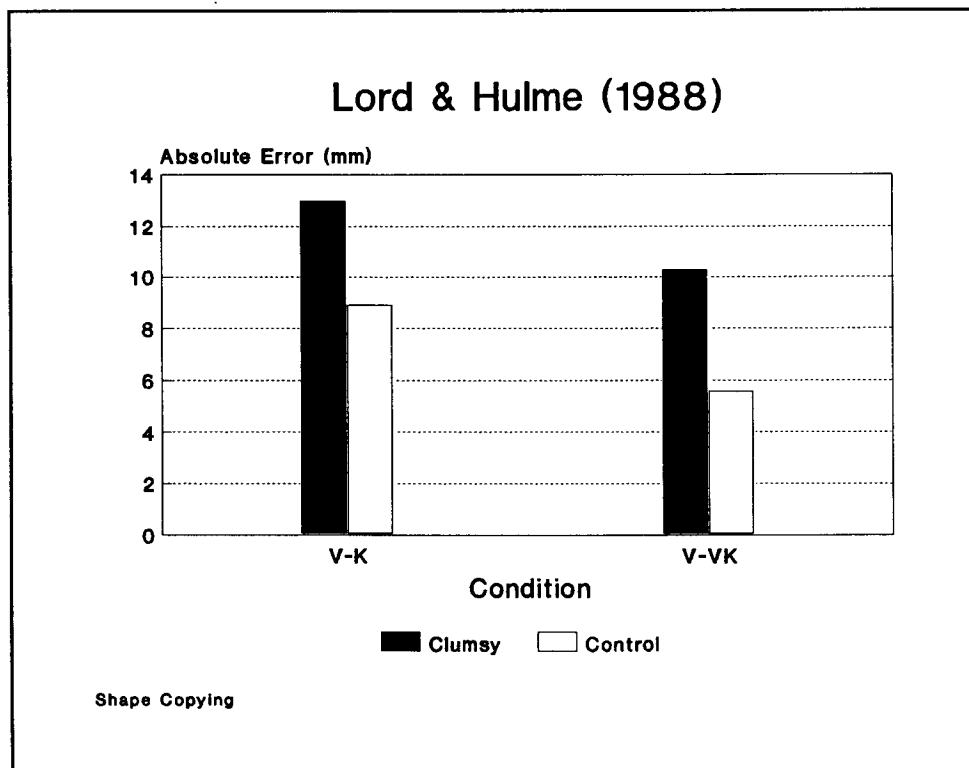
Figure 2g. Absolute angle errors in figure copying task with Clumsy and control children. Replotted from Lord and Hulme (1988)

addition to providing important information concerning target location. One explanation is that performing such a task without visual information is a strange and unnatural activity. This may cause apprehension and lead to poor performance. Another possible explanation is that vision may have an important role in focusing attention on the task and in its absence attention may be broken. Another explanation fits in with the notion that Clumsy children have kinaesthetic processing deficits. When vision is not available the system is forced to make use of information from other perceptual channels, such as kinaesthesis. If the processing of such information is not efficient then this is likely to result in control difficulties. Another possibility is that, even if the Clumsy children can make sense of the kinaesthetic information, they find it difficult to translate this into action.

There are three other studies of relevance to the debate about the sensitivity of Clumsy children to the removal of visual information (Lord and Hulme, 1988; van der Meulen et al., 1991a; 1991b). These can be distinguished from the studies described above by the point at which vision was manipulated and also by the different tasks employed. In the studies previously described the availability of vision was manipulated at the point of input ie when perceiving the length of a line or the location of a target. However, in the three studies described below, vision was always available at input but it was manipulated at the point of output or movement execution.

Lord and Hulme's study of visual perception and drawing ability (1988) has already been mentioned in section 2.4.1 above. Following their previous reports that Clumsy children have visuo-perceptual deficits, they set out to look at the relationship between visual perception and motor performance and also to examine the effect on normal and Clumsy children of manipulating visual information during performance. In relation to the latter aim, they predicted that because normal

children make more adequate use of visual information compared to Clumsy children, group differences would be evident when vision was available. In addition they predicted that when visual information was not available the normal children would be more severely affected and the group differences would diminish. These predictions are in direct opposition to the findings by von Hofsten and Rösblad (1992) and Jongmans (1989) outlined above.

Lord and Hulme's (1988) study employed a shape copying task. The stimulus, an equilateral triangle drawn on a card, was always visible. The availability of vision was manipulated at output. Thus, on a V-VK condition the child could both see and feel their drawing hand and monitor their output on paper. In a V-K condition vision of the drawing hand and output was occluded. In this study, Lord and Hulme failed to obtain the results they had predicted (see figure 2g). Although the Clumsy children produced more errors than controls in terms of shape reproduction, they found that **both** groups produced more errors when vision was not available at output and there was no interaction between group and condition. Further discussion of the results and an attempt to replicate this study is reported in chapter five.

Using yet another completely different task, Van der Meulen et al. (1991 a and b) manipulated the availability of vision in two studies with Clumsy children. The first, designed primarily to examine group differences in open-loop mechanisms (ie. those not using afferent information), employed a fast goal-directed arm movement. The second study, designed specifically to examine the influence of visual feedback mechanisms, employed a tracking task. In both, vision was always available to indicate the position of the target (in the former the target was stationary and in the tracking task it was moving). As with Lord and Hulme's study, the availability of visual information was manipulated at output. In a V-VK condition hand position was indicated by red light emitting diodes (leds), in a V-K condition vision of the hand

and leds was occluded. In the goal-directed reaching task they found that the Clumsy children performed more poorly in both conditions. They showed greater variability in both the distance moved during the acceleration phase of the movement (see figure 2h) and in the total distance moved compared to controls. Moreover, although there was a general tendency for variability to increase when vision was not available to guide movement, this was not significant and there was no difference between the groups with respect to this. The Clumsy children also had significantly longer movement times compared to controls, as shown in the lower portion of figure 2h. On this measure, the difference between the groups was only significant in the V-VK condition, when vision was available to guide movement.

The tracking task involved holding onto a handle and moving it along a straight, horizontal rail keeping it as close as possible to a target light which moved above the rail. In this task, van der Meulen et al. (1991b) found that tracking quality was worse in the Clumsy group compared to controls and worse in the V-K condition compared to V-VK (figure 2i). They did not find a group by condition interaction, indicating that the two groups of children were equally affected by the absence of visual feedback information.

The results from these studies which manipulated vision at output are comparable to each other. They all found that on some of the measures taken, performance in the V-K conditions was worse than that in the V-VK conditions. That is, performance deteriorated when vision was not available during movement execution. All of the studies also found that Clumsy children generally performed more poorly than controls. For all of the measures taken in the studies no significant group by condition interactions were found (except movement time, van der Meulen et al., 1991a).

Van der Meulen et al. (1991a and b) conclude from their results that clumsiness is not linked to a disturbance of the

van der Meulen et al. (1991a)

movement variability
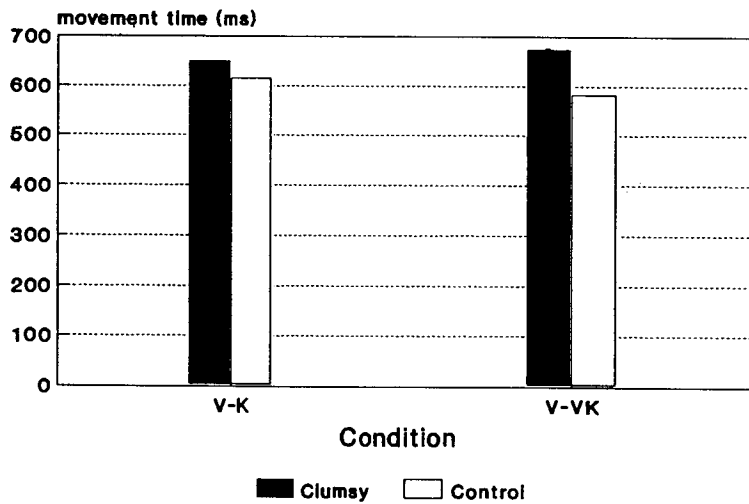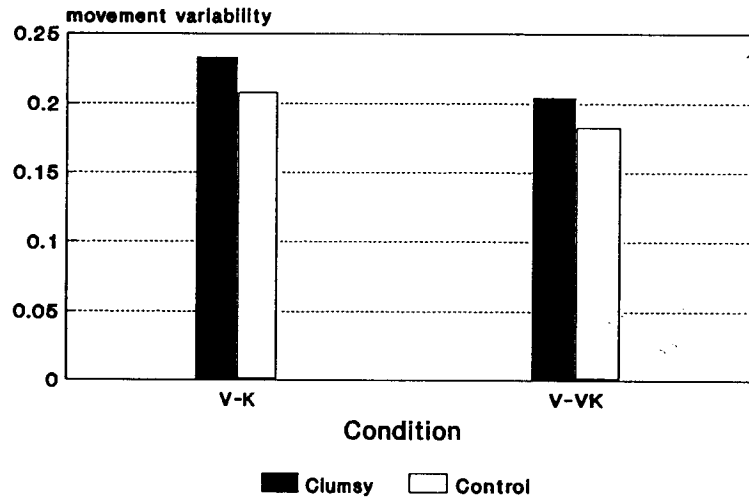
movement time (ms)

Fast Goal Directed Movement

Figure 2h. Fast goal-directed hand movements with Clumsy and control children. Replotted from van der Meulen et al. (1991a). Upper: Movement variability in acceleration phase. Lower: Movement time.

van der Meulen et al. (1991b)
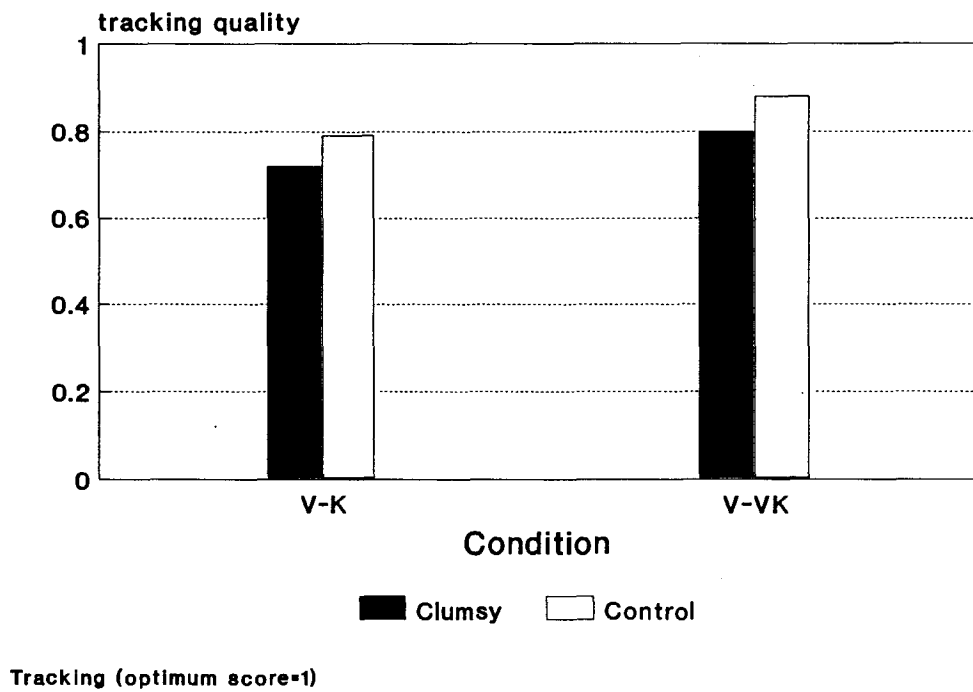
tracking quality

Figure 2i. Tracking quality in arm-tracking task with Clumsy and control children. Replotted from van der Meulen et al. (1991b).

integration of visual feedback information and motor processes. Lord and Hulme, however, suggest that their failure to find any significant interactions may have been due partly to the fact that vision was always available at the input stage for analysis of the stimulus. This, they suggest, may maintain the advantage of better visual perception in the control group even when vision of the drawing arm is occluded.

Although Lord and Hulme's initial predictions do not tie in with previous findings of enormous group differences in K-K compared to V-K conditions, their explanation of the results in terms of the availability of vision at input in both of their conditions may be useful. However, rather than viewing this as allowing the control children to maintain an advantage in the V-K condition, it may also be interpreted in another way. The fact that the stimulus can be seen during output may be more of an advantage for the Clumsy children. If Clumsy children have fundamental problems in making use of visual and/or kinaesthetic information then they may, when visual information is available to them, employ strategies to make maximum use of the visual information. That is, they may use all available visual cues in an attempt to overcome their fundamental difficulties. From the studies contained in the present review, support for this idea comes from van der Meulen et al's study on fast goal-directed movements. This is the only study in the review in which there is a time constraint (the movement is performed in 1 second) and in which movement time is measured. In this study it was found that the Clumsy children performed the task significantly more slowly than controls only in the V-VK condition, that is when vision was available to them both at the input and output stages (see lower portion of figure 2h). The suggestion that Clumsy children may rely more on visual information than controls also receives empirical support from other studies. In a study focusing on childrens' handwriting, Wann (1987) found that poor writers tended to have patterns of movement that allowed greater visual control during movement execution. There have also been suggestions that Clumsy children do

attempt to compensate for their difficulties. For example, as noted earlier, Forsström and von Hofsten (1982) found that in an interception task they used strategies, such as reaching ahead for the ball. The suggestion that Clumsy children have a greater dependence on visual information also ties in with the results from the pointing task. In this case the explanation for the results in the K-K task would be that the Clumsy children are more affected than controls because they do not have the visual information available to even attempt to compensate for their difficulties.

If Clumsy children do have problems with visual and/or kinaesthetic perception then they are provided with an imperfect assessment of environmental and bodily conditions. This may in turn affect the subsequent stages in planning, executing and evaluation movement. In the studies reviewed in this section, however, it is not possible to identify the stage or stages at which the problems occur.

2.5.4 Individual Differences

In those studies that have focused either on visual perceptual difficulties (eg Hulme et al., 1982; 1984) or kinaesthetic problems (Laszlo and Bairstow, 1985; 1986), the arguments have been presented as if there is a single deficit that is common to all Clumsy children. Although these authors do note that not all Clumsy children have these perceptual problems, little information is provided on individual differences. Group analyses also form the focus of other experimental studies with Clumsy children, although some do provide individual data.

For example, in addition to their group results, von Hofsten and Rösblad (1992) and Jongmans (1989) also provide individual data for the Clumsy children. Figure 2j shows the data from the 11 Clumsy children in von Hofsten and Rösblad's study. This is also shown in table 2.5 alongside the individual data from Jongmans (1989). From the table it can be seen that, although the highest proportion of children (41.65%) show the

von Hofsten and Rosblad (1992)

Absolute Error (mm)

Subjects

■ K-K   ▨ V-K   ☐ VK-K
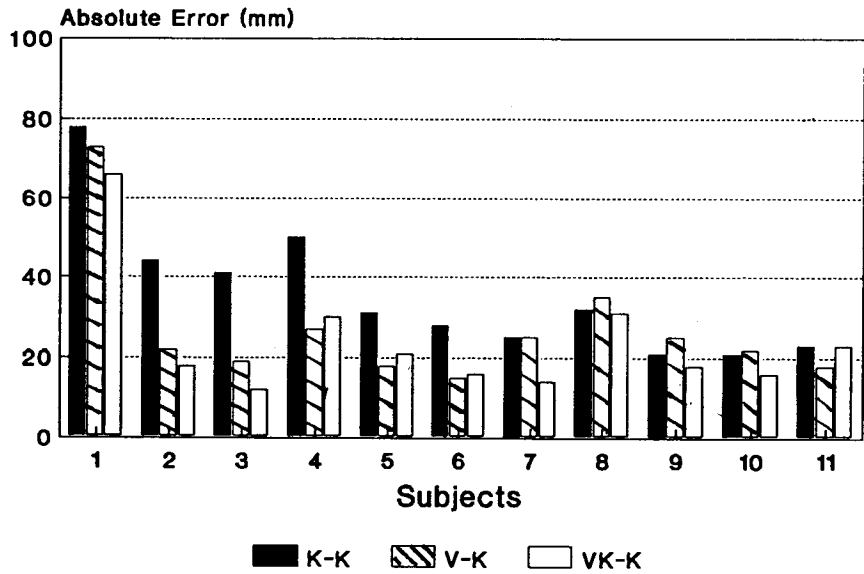
Pointing to Target

van der Meulen et al. (1991b)

tracking quality

Condition

■ Clumsy   ☐ Control
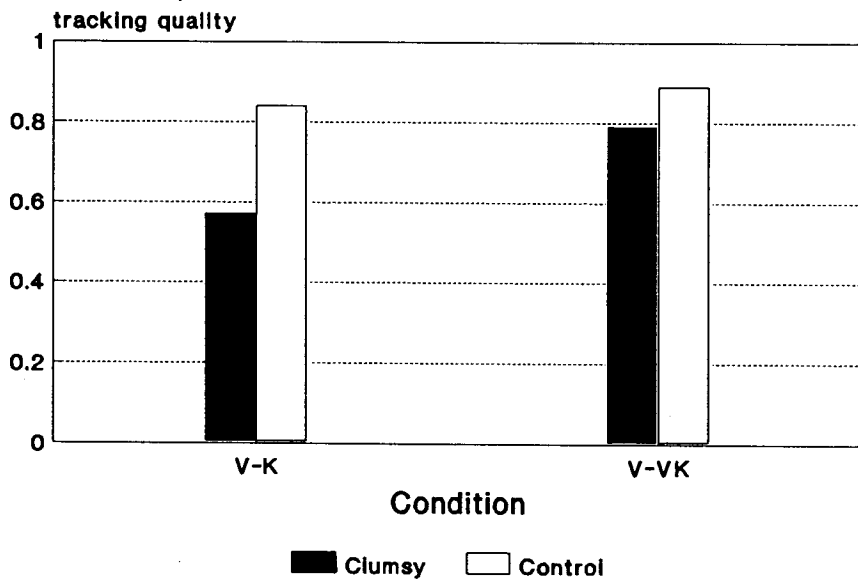
Tracking (optimum score=1)

Figure 2j. Data from individual Clumsy children.
Upper: Replotted from von Hofsten and Rösblad (1992).
Lower: Replotted from van der Meulen et al. (1991b).

pattern of the group results, 19.70% have the greatest errors when their reaching movements are directed visually. For example, subjects 8, 9 and 10 in figure 2j. This suggests that the visual processes might be the ones affected in these children.

Table 2.5 Percentages of Clumsy children displaying various magnitudes of absolute error in K, V and VK conditions in a pointing task. Taken from von Hofsten and Rösblad (1992) and Jongmans (1989).

Magnitude of Errors	von Hofsten & Rösblad	Jongmans	TOTAL
K > V ≥ VK	27.3	56	41.65
K > VK > V	27.3	24	25.65
K = V > VK	9.0	4	6.50
V > K > VK	27.3	12	19.70
K = VK > V	9.0	4	6.50

Less formal reports of individual differences are also available from other studies. For example, van der Meulen et al. (1991b) note that

"Tracking without visual feedback led to a pronounced increase in between-subject variability, ... which was approximately the same for both groups. This increased dispersion obviously reduced the possibility of distinguishing the groups".

They also provide the data from one pair of Clumsy and control children, shown in figure 2j, and report that

"The difference between the two with respect to the similarity in the shape of the target signal and tracking movement clearly increased if visual feedback was withdrawn".

Unfortunately this is the only individual data that is supplied. It would be interesting to know how many individual

Clumsy children display patterns of performance across the conditions that differ from those of the group results, as was noted in the studies by von Hofsten and Rösblad (1992) and Jongmans (1989).

2.5.5 Summary

Using tasks designed to measure purely visual or kinaesthetic abilities, a variety of studies report that Clumsy children have problems with one of these modes of perception. However, these have received considerable criticism regarding the methods used to measure perceptual skills and to relate these to motor competence.

Another way of examining the sensory perceptual skills of Clumsy children has been to compare how different types of perceptual information (vision and kinaesthesis) are used **within** a movement context. By manipulating the availability of visual information attempts have been made to examine the consequences of using different types of perceptual information (eg. vision only, kinaesthesis only or vision and kinaesthesis). The results from these studies have not been consistent. Some suggest that Clumsy children have particular problems with cross-modal tasks (translating visual information into movement) while others find that relying on kinaesthesis only (when vision is not available) presents particular problems for Clumsy children. Since a variety of tasks were used across this set of studies, the inconsistent results may reflect task differences more than anything else.

The tasks employed vary in their relevance to every day manual skills and the extent to which they might appeal to young children. For example, line-length matching tasks appear quite irrelevant, whereas shape copying is something children are often required to do at school (for example when learning to write).

A more general criticism of these studies relates to the way in which vision has been manipulated. In each case, vision has

been withdrawn either at the 'input' or 'output' stage of the task. Three problems emerge from this. Firstly, the distinction between perceptual input and motor output is rather artificial, especially when considering the more realistic tasks, such as copying and pointing to a target. Secondly, it produces tasks which are essentially cross-modal. This makes it difficult to interpret results based on comparisons across conditions since one condition is cross-modal and the other is intra-modal. The fact that modality may be a confounding factor has not been explored. Thirdly, in some of the studies this separation means that some visual information is still available during performance in all of the conditions.

Two further criticisms of these studies relate to the way in which performance has been measured. Firstly, a variety of tasks have been employed in the different studies but because different performance measures have been taken, it is difficult to compare the results. Secondly, as with the descriptive work, performance has largely been measured in terms of movement outcome, with little information available on movement quality.

A final criticism concerns the methods used in data analysis. Although all of the experimental studies reviewed in section 2.5.3 involve a comparison across performance in different conditions, some employ methods of analysis that do not allow for the investigation of interaction effects. This is a serious omission since the major question of interest is whether or not Clumsy children are more severely affected by the removal of vision compared to controls.

2.4.6 General Discussion

The purpose of this chapter has been to provide a selective review of the literature on clumsiness relevant to this thesis. The chapter began with a brief outline of two separate but complimentary approaches to the study of human behaviour generally. This distinction is maintained throughout this

thesis.

The descriptive work reviewed has served mainly to outline the range of problems that Clumsy children experience on manual tasks. In this section, the focus has been on two groups of tasks classified as 'graphic' and 'manipulative'. In the experimental section, the focus has been exclusively on one issue, visual and kinaesthetic processing problems in Clumsy children. Here, the range of manual tasks covered was determined by the studies reviewed. In both sections some of the studies were criticised for employing tasks that lack 'ecological validity' and for using a limited range of performance measures.

Two more general criticisms are also common to both approaches. Firstly, there has been little examination of age effects and no longitudinal data. Secondly individual differences are rarely investigated.

In this chapter, some major problems have been outlined within both the descriptive and experimental approach. The main aims of this thesis involve solving some of these problems and these are outlined in the following chapter.

AIMS OF THE THESIS

3.1 Introduction

The purpose of this chapter is to outline the aims of the research in this thesis. Most of these emerged directly from problems that were identified in the selective review of clumsiness presented in chapters one and two. They can be broadly divided into rather general objectives which are common to all of the studies presented and the more specific aims central to each section of the thesis.

3.2 General aims

To combine group and individual approaches

In chapter one it was noted that Clumsy children form a very heterogenous group. There is variation not only in the severity of their movement difficulties but also in their intellectual ability and the range of non-motor difficulties that they experience. This heterogeneity has implications for subject selection and assessment and for research design and analysis.

In studies with Clumsy children the process of subject selection is often inadequate. How it is dealt with in the present thesis is outlined in chapter four.

Although researchers commonly note variation within the Clumsy group, few have investigated individual differences in any further depth. There is, without doubt, a need for more group studies and these are undertaken in the thesis. However, this issue is also addressed by looking at sub-groups and individual differences within the groups.

To investigate changes in motor competence with age

In addition to the variation noted above, the manifestation of clumsiness also varies with age. The implications of this for

assessment were discussed in chapter one but generally the issue of whether and how the differences between Clumsy children and their age peers changes with age has received little attention in the study of clumsiness. One of the aims of this thesis is to address this issue by employing cross-sectional studies using a larger sample size and wider age range than has been used in previous studies. This makes it possible to describe the characteristics of Clumsy children of different ages and also to investigate interaction effects in the statistical analyses.

Although cross-sectional studies are useful and contribute much to our understanding of developmental disorders, longitudinal studies are also needed to document changes in **individual** children. In chapter one some longitudinal studies were described that followed individual Clumsy children over a number of years (eg, Losse et al., 1991). One of the aims of this thesis is to address the question of changes with age specifically in relation to the development of manual competence. However, within the confines of a PhD thesis, it is not possible to study children over an extended period of time. In this thesis the performance of a sub-set of the Clumsy children is investigated over an 18 month period.

To combine the descriptive and experimental approach

In chapter two the distinction was made between two approaches to the study of clumsiness, descriptive and experimental. Although there is overlap between these approaches, it is a useful distinction and one which is maintained in this thesis. Thus, both chapters five and six, each of which deal with a different aspect of manipulative function, are divided into two parts. In each chapter, the first part provides detailed descriptions of performance on manipulative tasks under normal conditions. In the second part an experimental approach is adopted to address the question of how vision functions in the control of the hands. Although this question is investigated rather differently in each chapter, in both, performance is examined with and without the availability of visual

information, a method discussed at length in chapter two.

Since these two approaches to the study of clumsiness are complimentary, this thesis aims to combine them. This is achieved by employing identical tasks and measures of performance wherever possible. The rationale for the choice of tasks is presented below.

Choosing 'ecologically valid' tasks

In chapter two some of the tasks previously chosen for the study of clumsiness were criticised for being too constrained and lacking ecological validity. Thus, in this thesis, another important aim was to select tasks that are relevant to the skills required by children in their everyday lives. From the various options possible, two classes of task were selected: drawing and object manipulation.

Drawing Tasks:

Chapter five of the thesis, focuses on drawing skills. These were selected for study in preference to writing skills since the latter may be influenced by other factors such as language, spelling, teaching methods etc.

In chapter two it was noted that no detailed descriptive work exists on the free drawing skills of Clumsy children, even though they are performed frequently and spontaneously by most children, including those more severely impaired than Clumsy children (Freeman, 1980). In order to provide some descriptive information on free drawing, a human figure drawing task was employed, which is both familiar and appealing to children. In addition to the obvious motor component of this task, considerable cognitive and perceptual skills are also required in order to decide what to draw, to plan where to start and position parts on the page, to represent the correct proportions of the figure and so on.

For the experimental analysis of drawing skill, the task was changed from figure drawing to shape copying. There were three

reasons for changing the task. Firstly, keeping track of the spatial layout of a free drawing is impossibly difficult without vision. Secondly, the use of another drawing task offered the opportunity to investigate the consistency of the childrens' performance over a range of graphic tasks. Third, and most importantly, it was decided to undertake an exact replication of the study by Lord and Hulme (1988) which employed a shape copying task.

Object Manipulation Tasks:

Chapter six of the thesis focuses on object manipulation skills of Clumsy children. As noted in Chapter two, there have been few investigations into the performance of Clumsy children on manipulative tasks which are important in everyday life. In this thesis two quite different tasks have been selected, both of which are familiar to children and interesting to perform. The first is a peg insertion task which has many similarities to familiar, everyday tasks (eg putting coins in a purse or pins in a box). Most children will have previously encountered similar tasks since completing peg boards and posting shapes are common pastimes in school. The second task, button fastening, is a commonly performed self help task. By the age of five most children have attempted, if not succeeded, in buttoning their clothes.

In both of these tasks a small object has to be manipulated in the hand and placed in a target position. However, there are some important differences between them. Firstly, in the peg insertion task one hand plays the primary role, handling the object and transporting it to the target. The other hand has a secondary role and may be used to steady the board and help search for the target. In contrast, the buttoning task involves the coordination of both hands to open up the hole and manoeuvre the button through it. Secondly, in the peg insertion task the target is fixed (the holes in the board do not move) whereas the target in the buttoning task is less fixed (the position of the button hole will change if the material is moved). Lastly, the tasks may differ in the extent

to which they are practised by the children. Buttoning may be performed (or at least attempted) every morning when a child gets dressed. In contrast, tasks like peg insertion are not performed with such regularity.

These two tasks were selected as being suitable for the age range of subjects following some preliminary work. They had to be simple enough for the youngest Clumsy children to experience some success and yet also interesting for 11 and 12 year olds. Forsström and von Hofsten (1982) have pointed out that although simple or familiar tasks may seem to be performed well by children with movement difficulties, on careful scrutiny important differences may be noted, which may hamper performance in more complex tasks or with increased task demands.

3.3 Specific Aims
The aims described above relate to general issues and are relevant to all of the research reported in this thesis. In addition, however, within the descriptive and experimental sections of the thesis rather more specific aims are concerned with the execution of drawing and object manipulation tasks. These are outlined below.

To describe performance under natural conditions
In chapter two a review of some of the descriptive work concerning the manual skills of Clumsy children was presented. It was noted there that most of the studies have only described performance in terms of movement 'outcome', using measures of speed and accuracy. Little information is available on the quality of movement in the performance of manipulative tasks. It should be noted that it is both difficult and time consuming to gather information on movement quality because, not only do movements take place quickly, but they are extremely difficult to describe and document.

The major aim of the descriptive section of this thesis is to describe performance on two quite different groups of tasks.

Since the attempts to collect data to describe performance differed slightly for each set of tasks, the objectives for each type of activity are described separately below.

Drawing Tasks:

The first objective was to obtain a permanent record of performance to aid the recording of data. This was achieved quite simply by collecting the children's drawings on paper. Although a drawing is strictly the product or 'outcome' of performance, it also reflects movement quality in that it is produced throughout the movement and not just at completion.

The second objective was to use checklists to gather information systematically. In addition to yielding an overall performance measure, these checklists permitted the examination of different aspects of movement. In the case of drawing, such a checklist already exists. The Goodenough-Harris 'Draw a Man' Test (Harris, 1963) has well established norms for overall drawing performance. In addition, O'Connor and Hermelin (1987) have proposed a sub-division of this test into four categories, each reflecting a different aspect of performance, described as motor control and coordination, the representation of proportions, feature depiction and feature detail. As far as this thesis is concerned, the most important distinction is that between aspects of pure motor control, as observed in such things as the quality of line, and other dimensions of drawing ability.

Another objective was to report the reliability of the observations. The Goodenough-Harris test already has proven reliability and this was re-checked in the investigation.

In the case of the shape-copying task, there was a restriction in the measures that could be taken due to the fact that this was a replication of a previous study. In the original study, two performance measures were recorded, one reflecting the child's ability to represent the shape of the stimulus triangle and one reflecting the ability to represent size. In

the latter case, however, deviation from the correct size was measured without reference to direction. For example, a recorded error of 5cm may reflect either that the lines of the triangle were 5cm longer or that they were 5cm shorter than the stimulus. In the replication of this study, one additional measure was included. This concerned the direction of size errors (ie whether the copy was bigger or smaller than the stimulus).

Object Manipulation Tasks:

With these tasks, the first objective was to describe performance in terms of movement time, a measure which is both easy to obtain and reliable. The second objective was to combine this information on movement outcome with information on movement quality to provide a comprehensive description of performance.

As with the drawing tasks, permanent records of performance were collected. In this case, however, these were obtained by making video recordings of the children performing the tasks.

In contrast to the figure drawing task, no appropriate checklists were available for the peg insertion and buttoning tasks. The development of observational checklists, therefore, was a major part of the investigation and is described in detail in Appendix 3. The checklists were designed with a similar structure and content for both tasks so that some comparison could be made across them.

In order to make maximum use of the data available from the checklists, this was treated in various ways. Firstly, overall quality was considered in terms of a composite score. This permitted an examination of the relationship between overall speed and movement quality which has not previously been done. Secondly, groups of items were examined which were considered to reflect different aspects of performance (including motor control and spatial and force characteristics). Finally, individual items were particularly useful for looking at age

changes.

As above, these checklists were tested for both intra-rater and inter-rater reliability.

To examine the role of vision in performance
In chapter two a selective review of work on visual and kinaesthetic processing in Clumsy children was presented. The major aim in the experimental sections of this thesis was to continue with this line of investigation. As for the descriptive work above this was achieved in quite different ways in the drawing and object manipulation tasks. Once again, therefore the objectives for each are outlined separately below.

Drawing: A large part of the review in chapter two addressed the question of whether visual perceptual deficits were the cause of movement difficulties in Clumsy children. Several problems with the existing research in this area were outlined and the question requires further investigation.

This thesis aimed to address some of the issues by attempting a replication of the study by Lord and Hulme (1988). They measured visual perceptual ability independently of a drawing task, then used a correlational method to examine the relationship between visual perceptual abilities and motor competence.

Their method was replicated precisely and their study extended in two ways. Firstly, as noted above, an additional error measurement (constant error) was used. Secondly, the investigation of the relationship between visual perceptual ability and motor competence was extended by including two additional motor measures (general motor competence and figure drawing ability).

Also included in this study was an examination of the effect of removing visual feedback information on performance of the

drawing task. There are several problems in the way that this was undertaken but these could not be avoided because this was a replication. These problems were addressed in the studies employing manipulation tasks described below.

Object manipulation: This section of the thesis focuses entirely on the role of vision in the control of manipulative action. In this case, the only method employed involved the removal of visual information during performance. A number of criticisms of the studies which have adopted this methodology have been made. The main aim of this section was to expand and improve upon this body of work by addressing these criticisms.

One of the criticisms concerned the division of tasks into 'input' and 'output' stages and the subsequent removal of visual information at only one of these stages. These problems were avoided by employing the peg insertion and buttoning tasks described above. These are quite natural and cannot easily be divided into 'input' and 'output'. Thus, in the experimental manipulations, visual information was removed throughout the entire task.

Another objective of this study was to show which particular components of performance were most affected by the removal of vision and to examine the possibility that these effects were age related.

The final objective was to employ analyses specifically to look at interaction effects between Clumsy and control children and the various task conditions. As mentioned in chapter two, some previous studies have failed to do this.

Chapter Four

SUBJECT SELECTION AND DESCRIPTION

4.1 Introduction

In chapter one, a number of points relevant to the selection
and description of subjects for research purposes emerged. A
discussion of the problems associated with defining the
condition, clumsiness, illustrated the heterogeneity of this
population and the need to assess a number of aspects of
development. Various issues concerned with the measurement of
these have been highlighted and at present the selection and
description of these children must depend on a combination of
criteria.

The primary feature of clumsiness is defined in DSM-III-R as
a "marked impairment in the development of motor coordination"
(DSM-III-R, 1987). Clearly for research purposes the first
question to be addressed is how this impairment in motor
coordination can be comprehensively, accurately and reliably
measured. There are a number of issues to address. The
assessment must be age appropriate since the manifestation of
clumsiness changes with age. It is also essential that the
assessment includes both fine and gross motor skills because
the range of problems varies from child to child. The
assessment must also be psychometrically sound and have UK
norms.

In this thesis, the Test of Motor Impairment (Stott, Moyes
and Henderson, 1984) was chosen to identify the essential
feature of clumsiness. This test is specifically designed for
identifying children with a motor impairment and fulfils all
of the above requirements. British norms have been established
for all of the test items for children from 5 to 12 years old
and it's reliability and validity are well established
(Henderson and Hall, 1982; Lam and Henderson, 1987; Henderson,
1992). This test, or parts of it, have been used in many other
studies of Clumsy children (eg van Dellen and Geuze, 1988;

Schoemaker, 1992)

The DSM-III-R entry states that the condition is "not explainable by mental retardation" and is "not due to a known physical disorder" (DSM-III-R, 1987). Selection of the children therefore has to take place partly by exclusion, which is not entirely satisfactory.

An assessment of intelligence is essential in order to ensure that the child's motor problems are not part and parcel of more generalised delayed development that includes impaired cognitive functioning, poor language development etc. In order to identify "mental retardation" an assessment instrument is needed in which performance can be compared to norms. As noted in chapter one, several problems arise in choosing a method of assessing cognitive function in Clumsy children. For example, children with movement difficulties may lack the means to display their cognitive ability because of their motor and perceptual problems. This may be overcome by employing a verbal measure of cognitive ability. However, since many of these children also have language and speech problems, even the results of verbal assessments need to be interpreted with caution.

The test chosen to measure intelligence in this thesis was the Weschler Intelligence Scale for children - Revised Edition (1974), henceforth referred to as the WISC-R. A major advantage of the WISC-R over other tests (such as the Stanford-Binet Intelligence Scale) is that it allows for verbal and performance IQ to be measured separately. Verbal IQ provides a measure of the cognitive ability of Clumsy children which is uncontaminated by their motor and/or perceptual problems and was used as the primary measure of intelligence in this thesis. The WISC-R has American norms for children aged 5 to 15 and yields an intelligence quotient with a mean of 100 and a standard deviation of 15. Weschler (1974) suggests that an IQ of 80-119 represents an average score, 70-79 is borderline and anything below this reflects

mental deficiency. To ensure that all of the children participating in this project were of at least average intelligence, only those with verbal IQ scores equal to or greater than 80 were selected. Although not used for identification purposes, in parts of this thesis the measure of performance IQ has been studied in conjunction with other measures of motor competence. The short form of this test is used in this thesis. It is well validated against the full version (Sattler, 1974) and has been used extensively in studies with Clumsy children (eg Lord and Hulme, 1987; 1988; Losse et al., 1991).

It is also important to eliminate those children suffering from known physical or neurological problems. This can generally be achieved on the basis of clear physical signs known to be associated with particular disorders, for example, abnormally elevated levels of creatine phosphokinase in the case of Muscular Dystrophy and severe abnormalities of reflexes, posture or tone in the case of Cerebral Palsy. In this thesis it was not possible to perform a physical examination of the children. However, by consulting medical and school records, a broad distinction could be drawn between children who suffered from a known condition and those who did not. As noted in chapter one, many Clumsy children exhibit 'soft' signs of neurological dysfunction. In view of the fact that there continues to be some debate about the significance of these physical signs it was considered important to document them.

As noted in chapter one, delays in other areas of development are commonly associated with clumsiness. Although no formal assessment is made of associated features in this thesis, information on other learning difficulties, emotional, social and behavioural problems experienced by the children are noted.

Further details of the chosen assessments are described in detail below. This is followed by the group and individual

data.

4.2 Method

4.2.1 Subject Selection
Clumsy Group

In order to select children for the experimental group, we approached three professionals particularly interested in clumsiness and who currently worked with Clumsy children. These were two Occupational Therapists (OTs) working at hospital-based Child Development Centres (CDCs) and a Physical Education Advisory teacher working in primary schools. They selected for us children who they considered to be Clumsy.

Control Group

For each Clumsy child thus selected, a control child was selected of the same age (within 6 months) and sex and from the same type of school. The children were also matched as closely as possible on verbal IQ.

Consent for the children to participate in the project was obtained from the children themselves and from their parents.

4.2.2 Procedure

Each child was tested individually either at the CDC they were used to attending or at their school. The entire testing session lasted between 40-60 minutes. School and/or medical records were later examined.

Assessment of motor competence

All of the children were first tested on the Test of Motor Impairment (Stott, Moyes and Henderson, 1984) henceforth referred to as the TOMI. This test is arranged in four age bands to be used with children aged five and six, seven and eight, nine and ten and eleven plus. Each age band is identical in organization and contains eight items, the difficulty level of which vary with age. Each test item is assigned a score of 0, 1 or 2; 0 denotes acceptable

performance (obtained by 85% of the distribution), 1 denotes borderline performance (obtained by 10% of the distribution) and 2 indicates failure (obtained by 5% of the distribution). The test items fall into three categories: manual dexterity (3 items), ball skills (2 items) and balance (3 items). Test performance may be expressed in terms of individual item scores (out of 2), category scores (out of 4 or 6) or total scores (out of 16). The higher the score, the less competent the child.

Assessment of intelligence

Each child was then tested on the short version of the WISC-R. This consists of four sub-tests: the Similarities and Vocabulary tests from the Verbal section and the Block Design and Object Assembly from the Performance section. Using the scaled scores on these items, estimates of verbal and performance IQ can be derived which correlate quite highly with those obtained on the whole test (Sattler, 1974).

Physical and neurological status

Prior to the commencement of this project all of the Clumsy children selected by OTs had undergone a thorough physical and neurological examination by a paediatrician. Similarly, all the Clumsy children selected by the Advisory teacher had undergone examinations by a school doctor. Permission was granted for the medical and/or school records of each Clumsy child to be consulted. Details were noted from these records regarding the mention of any serious physical disorder, the detection of 'soft' neurological signs or any adverse medical events including problems at birth.

Associated features

The medical and/or school records of the Clumsy children were also consulted to obtain information on other features that are often associated with clumsiness. Every mention of non-motor learning difficulties such as difficulties with language or number work was noted, as was any mention of behavioural, emotional or social problems. This information from the

childrens' records was supplemented by comments from the children themselves, their parents, teachers and therapists.

4.3 Results

4.3.1 Subjects

42 Clumsy children were referred to us: 14 girls and 28 boys. The children ranged in age from 5 years, 3 months to 12 years, 11 months. There were 3 infant, 34 junior and 5 secondary school pupils in the sample. Whereas we found a ratio of 1 girl to every 2 boys, the ratio is usually 1:3. There were, however, no significant sex differences in the Clumsy group in terms of motor competence or IQ scores.

The number of children in the four TOMI age bands can be seen in table 4.1, while table 4.2 shows the mean age of children in the Clumsy and control groups. Table 4.5 shows individual data for the age and sex of the Clumsy children.

Table 4.1. Number of children in each age band

	CLUMSY	CONTROL
AGE BAND:		
5-6 years	10	10
7-8 years	11	11
9-10 years	11	11
11+ years	10	10
TOTAL	42	42

At the time of testing, 8 children in each group were attending a school for children with moderate learning difficulties, the others all attended mainstream outer London schools. In the studies reported later in this thesis, no distinction has been made between those children originally selected from mainstream schools and those from special schools. In general, we found that the Clumsy children in special schools were no different to those in mainstream

education in terms of the extent of their movement problems. Although their IQs were, on average, slightly lower than those in mainstream school, we found one case in which a Clumsy child with a verbal IQ of 122 was transferred into special education because the teachers felt that he needed help for his movement difficulties that they could not provide.

4.3.2 Motor Competence

The group results are summarised in table 4.2 and figure 4a. It can be seen that the two groups are clearly distinguished and the difference between them is statistically significant (t=15.43, df=82, p<.0005). All of the Clumsy children obtained a total TOMI score equal to or greater than 4.5 which suggests at least a moderate motor impairment and places them below the 15th percentile for their age. There is considerable variation in their difficulties, with some only just below this point whereas others failed to pass any item on the test. All of the control children obtained total scores of 3.5 or less, denoting acceptable performance.
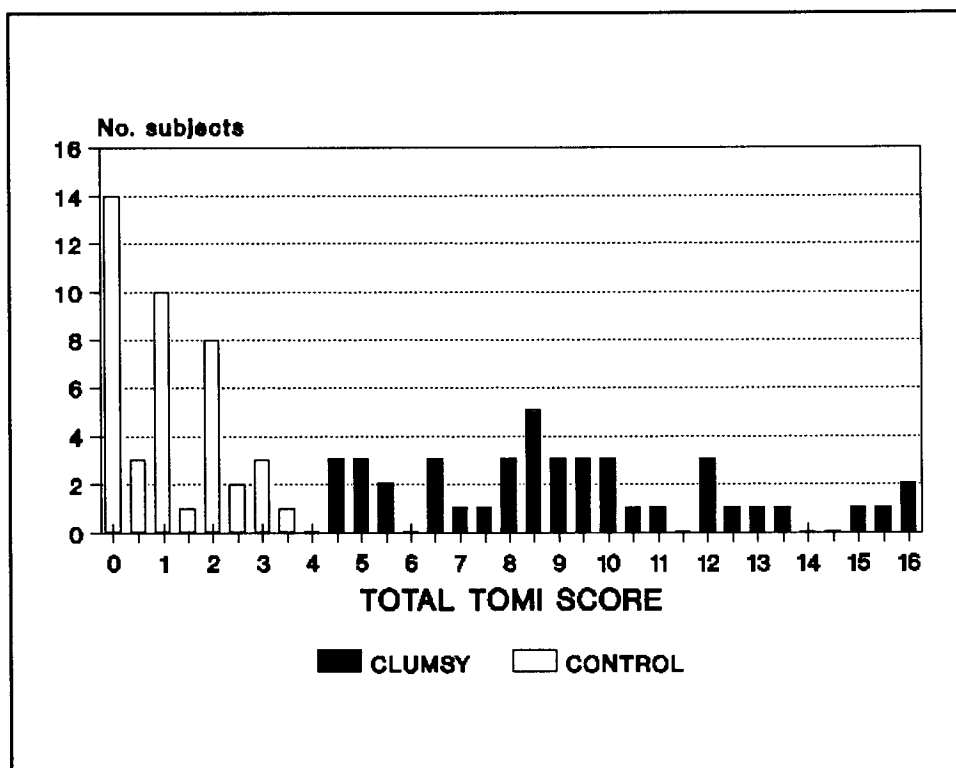
Figure 4a. Total TOMI score for Clumsy and control groups

Table 4.2. Age, TOMI and WISC-R results of Clumsy and control groups

		CLUMSY	CONTROL
AGE: (months)	mean SD range	106.6 24.3 63-155	107.0 ns 29.0 63-160
TOMI:	mean SD range	9.16 3.21 4.5-16	1.12 ** 1.05 0-3.5
WISC-R: VERBAL IQ	mean SD range	95.10 14.97 80-127	98.79 ns 10.11 81-122
PERFORMANCE IQ	mean SD range	81.76 17.40 54-120	105.43 ** 14.03 78-136

** p<.001
ns not significant

The category scores and total scores are given for individual Clumsy children in table 4.5. The former show that whereas most of the Clumsy children experience difficulties in all three areas of motor performance, there are 12 who perform quite well in one of the categories. For example, there are 6 Clumsy children who score 0.5 or less for manual dexterity, 3 score 0.5 or less for ball skills and 3 score zero for balance.

4.3.3 Intellectual Capacity

The group results for verbal and performance IQ are shown in table 4.2 and the individual results for the Clumsy children are given in table 4.5. Although both components of the WISC-R were administered, the verbal component was used as the matching variable as it provides a measure of cognitive ability uncontaminated by perceptual and/or motor difficulties. By matching the two groups of subjects on this dimension, therefore, we can be confident that there are no differences in the kinds of cognitive processes that are

associated with verbal ability and conceptual thinking. As can be seen from table 4.2 the difference between the two groups is small and not statistically significant (t=1.30, df=82, p<.196).

On the performance component of the WISC-R, the difference between the two groups was statistically significant (t=6.96, df=82, p<.0005). This finding has been reported in some studies of Clumsy children (eg Lord and Hulme, 1987; 1988; Hulme, Biggerstaff, Moran and McKinlay, 1982) but not in others (eg Henderson and Hall, 1982). Since visual perceptual and perceptuo-motor difficulties do not invariably co-occur in children of this type, it is perhaps not surprising that there is variation from one study to another (see chapter five for further discussion).

4.3.4 Physical and Neurological Status

Although the exact nature of the assessments by paediatricians and school doctors were not reported in the medical and school records, it was possible to determine that the possibility of a serious physical condition, such as Muscular Dystrophy or Cerebral Palsy had been excluded. Although there was no mention of a serious physical disorder for any of the Clumsy children, some other medical problems were noted. These are summarised in table 4.3, with individual results shown in table 4.5. As shown, 18 Clumsy children were noted to have had past or present problems with their sight and/or hearing. Although no hard signs of neurological dysfunction were found for any child, six had been noted to exhibit some kind of 'soft' neurological signs. These included slight hypotonia and hypertonia, some associated movements and slight asymmetry of reflexes. Four children had at some time been noted as having a squint and 17 had been born prematurely or had a problematic birth.

Table 4.3. Number of Clumsy children noted to have medical problems

Nature of problem:	No. children
Problems with sight	10
Problems with hearing	8
Soft signs	6
Presence of squint	4
Premature and/or problematic birth	17

4.3.5 Other problems

Table 4.4 shows the range of social, emotional or behavioural problems that were mentioned in the records and the number of Clumsy children for whom these were noted. Table 4.5 shows, for each Clumsy child, whether or not any such problems were noted in their records.

Table 4.4. Number of Clumsy children noted to have social, emotional and behavioural problems

Nature of problem:	No. of children:
Social problems/no friends	25
Lacks confidence	22
Anxious	10
Poor concentration/easily distracted	19
Overactive	7
Naughty	8
Disorganised	4
Aggressive	3

Table 4.5. Individual data for 42 Clumsy children showing sex; age (yrs, months); scores from TOMI for manual dexterity (MD), ball skills (BS), balance (BAL) and total; verbal and performance IQ (VIQ, PIQ); presence of learning, social/emotional and behavioural difficulties; presence of 'soft' neurological signs and presence of adverse medical events.

No.	Sex	Age	TOMI MD	BS	BAL	Total	VIQ	PIQ	Learn.	Soc/ emo.	Beh.	Soft signs	Adverse medical events
01	M	5,3	6.0	2.0	4.0	12.0	82	69	Yes	Yes	Yes	Yes	Yes
02	M	5,3	2.5	3.0	0.0	5.5	103	100	No	No	Yes	-	-
03	M	6,0	6.0	1.0	6.0	13.0	83	94	Yes	Yes	No	Yes	No
04	M	6,8	4.0	2.0	2.0	8.0	86	75	Yes	Yes	Yes	Yes	Yes
05	M	6,10	2.5	2.0	2.0	6.5	83	86	Yes	Yes	Yes	Yes	-
06	F	5,10	2.0	1.0	1.5	4.5	123	106	No	No	No	Yes	No
07	F	6,8	2.5	2.0	3.0	8.5	106	86	Yes	Yes	No	-	No
08	F	5,6	6.0	2.0	4.0	12.0	83	61	Yes	Yes	No	Yes	Yes
09	M	6,2	4.0	2.0	3.5	9.5	115	84	No	Yes	Yes	Yes	-
10	M	6,0	4.0	4.0	0.0	8.0	106	91	Yes	Yes	No	Yes	Yes
11	M	7,2	1.5	2.5	2.5	6.5	106	94	Yes	Yes	No	Yes	No
12	M	7,3	1.5	4.0	3.0	8.5	122	106	Yes	Yes	No	Yes	No
13	M	8,2	4.0	2.0	4.0	10.0	86	72	Yes	Yes	No	Yes	Yes
14	M	7,5	4.5	0.0	4.0	8.5	92	78	Yes	Yes	No	Yes	No
15	M	7,5	0.5	3.0	1.5	5.0	97	120	No	No	No	-	-
16	M	7,5	2.0	0.5	2.5	5.0	83	89	Yes	Yes	No	-	-
17	M	7,10	4.5	4.0	5.0	13.5	80	72	Yes	Yes	No	Yes	No
18	F	7,4	4.0	4.0	2.0	10.0	88	86	Yes	Yes	Yes	Yes	No
19	F	7,8	6.0	3.0	6.0	15.0	83	58	Yes	Yes	No	Yes	Yes
20	F	8,2	5.0	3.5	4.0	12.5	97	64	Yes	Yes	Yes	Yes	No
21	M	8,5	6.0	4.0	6.0	16.0	83	72	Yes	Yes	No	Yes	Yes
22	F	9,2	3.0	4.0	2.0	9.0	81	66	Yes	Yes	Yes	Yes	No
23	M	9,0	3.0	4.0	2.5	9.5	114	72	No	Yes	Yes	Yes	No
24	M	9,9	0.0	2.0	2.5	4.5	103	106	No	No	No	No	Yes
25	M	10,0	6.0	4.0	6.0	16.0	89	94	Yes	No	No	Yes	Yes
26	M	10,1	0.5	4.0	4.0	8.5	103	94	Yes	Yes	No	No	No
27	M	10,1	1.0	4.0	4.5	9.5	82	72	Yes	Yes	No	-	-
28	M	10,5	4.5	2.0	1.5	8.0	81	58	Yes	No	No	Yes	No
29	M	10,6	0.0	2.0	2.5	4.5	84	108	Yes	No	No	No	No
30	F	9,1	1.5	4.0	3.0	8.5	105	97	No	Yes	Yes	Yes	No
31	F	9,10	1.0	2.0	2.0	5.0	81	58	Yes	No	Yes	-	-
32	F	10,1	2.0	4.0	4.5	10.5	83	72	Yes	Yes	Yes	-	Yes
33	M	11,3	2.5	1.0	3.0	6.5	114	73	No	Yes	No	Yes	No
34	M	12,8	6.0	3.5	6.0	15.5	81	55	Yes	Yes	No	-	No
35	M	12,11	6.0	0.0	3.0	9.0	127	108	No	Yes	Yes	Yes	-
36	F	11,3	0.0	4.0	3.0	7.0	84	70	Yes	Yes	Yes	Yes	Yes
37	F	12,10	2.5	2.5	5.0	10.0	81	61	Yes	Yes	Yes	Yes	-
38	F	11,2	2.0	4.0	5.0	11.0	84	54	Yes	Yes	No	-	-
39	F	11,6	0.5	4.0	1.0	5.5	83	68	Yes	Yes	No	Yes	Yes
40	M	12,1	3.5	3.5	5.0	12.0	114	97	Yes	Yes	No	Yes	-
41	M	12,3	5.0	2.5	0.0	7.5	113	86	No	Yes	No	No	-
42	M	12,8	4.0	2.0	3.0	9.0	123	102	No	Yes	Yes	Yes	-

- not recorded

4.4 Discussion

The methods employed for selecting subjects for this project have been described in detail allowing for comparisons to be drawn with other studies. The now popular TOMI has been used to set the criteria for inclusion in the Clumsy group and to quantify the extent of the Clumsy childrens' motor difficulties. All of the children in the Clumsy group have at least a moderate motor impairment and lie in the bottom 15% of the normal distribution in terms of their motor competence.

All of the Clumsy children also have verbal IQs at least in the low-average range and none have a known neurological disease. However, the medical and/or school records consulted revealed that many of the children in the Clumsy group experienced a range of learning difficulties (for example with language and number work) as well as difficulties with various social and emotional skills.

Forty two Clumsy children between the ages of 5 and 13 were selected. This sample is characterised by having a higher proportion of girls than is normally reported in studies with Clumsy children. Provision for the selected Clumsy children was found to be quite varied. Due to the nature of our selection procedure all had received some help from either the OT or the Advisory P.E. teacher who had put them forward for inclusion in the study. These two types of provision are very different in that a child is seen individually by an OT usually on a weekly or fortnightly basis, while a child seen at school by an Advisory P.E. teacher may receive help in a group in the form of extra P.E. lessons. In addition, the content of this help varies due to the very different professional backgrounds of teachers and OTs. School provision for Clumsy children varies in itself, with some in special schools and others in mainstream education. During the course of our project six children in our Clumsy group were transferred from mainstream to special schools.

4.5 Number of subjects in each study:

While some of the studies reported in this thesis involve all 42 of the Clumsy children described earlier, others involve a sub-set of

16 of these children. For ease of reference the data for these 16 Clumsy children is reproduced from table 4.5 and presented in table 4.6.

Figure 4b shows the number of Clumsy children participating in each study, either all 42 or the sub-set of 16. The first two studies reported in chapters five and six are entirely descriptive in approach and identical in design and organisation. As seen from the figure, in both chapters a cross-sectional study is reported which involves all 42 Clumsy children, plus their age-matched controls. This is followed by a longitudinal study, involving a sub-set of 16 of these Clumsy children.

The third study reported in chapters five and six is experimental in approach, focusing on the role of vision in performance. In this case, the studies in each chapter are organised quite differently. In chapter five, the experimental study involves the same sub-set of 16 Clumsy children plus their age-matched controls. In chapter six, the experimental study involves all 42 Clumsy children plus their controls.

Figure 4b. Number of Clumsy children participating in each study of this thesis.

CHAPTER FIVE Drawing Tasks		CHAPTER SIX Object Manipulation Tasks
Cross Sectional Study	42	Cross Sectional Study
Longitudinal Study	16	Longitudinal Study
Study on role of vision	16 42	Study on role of vision
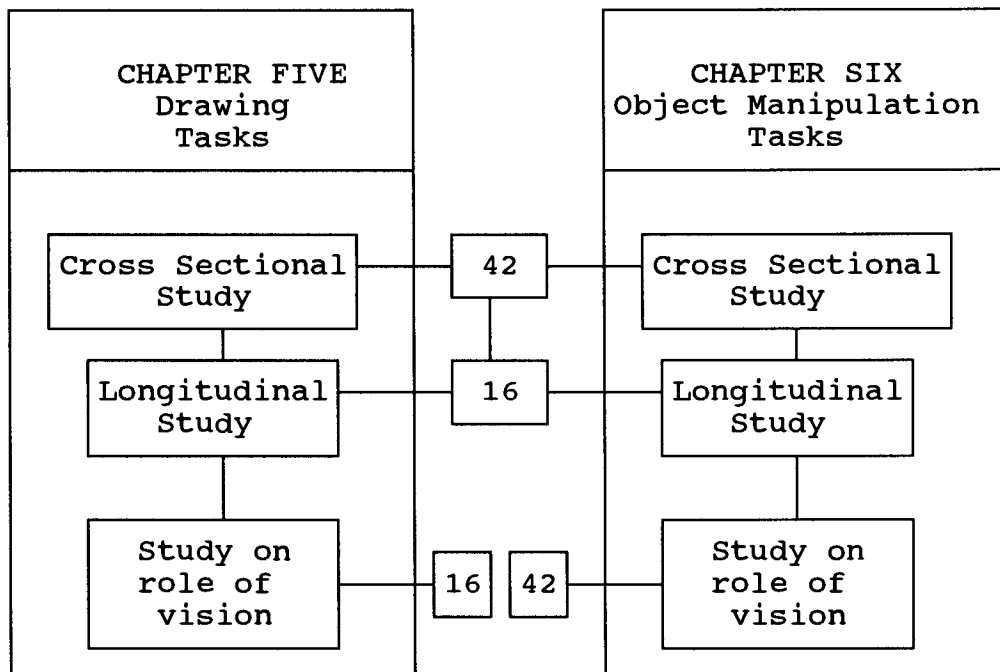
Table 4.6. Individual data for 16 Clumsy children showing sex; age (yrs,months); scores from TOMI for manual dexterity (MD), ball skills (BS), balance (BAL) and total; verbal and performance IQ (VIQ, PIQ); presence of learning, social/emotional and behavioural difficulties; presence of 'soft' neurological signs and presence of adverse medical events.

No.	Sex	Age	TOMI MD	BS	BAL	Total	VIQ	PIQ	Soc/ Learn.	emo.	Beh.	Soft signs	Adverse medical events
01	M	5,3	6.0	2.0	4.0	12.0	82	69	Yes	Yes	Yes	Yes	Yes
03	M	6,0	6.0	1.0	6.0	13.0	83	94	Yes	Yes	No	Yes	No
06	F	5,10	2.0	1.0	1.5	4.5	123	106	No	No	No	Yes	No
08	F	5,6	6.0	2.0	4.0	12.0	83	61	Yes	Yes	No	Yes	Yes
11	M	7,2	1.5	2.5	2.5	6.5	106	94	Yes	Yes	No	Yes	No
12	M	7,3	1.5	4.0	3.0	8.5	122	106	Yes	Yes	No	Yes	No
13	M	8,2	4.0	2.0	4.0	10.0	86	72	Yes	Yes	No	Yes	Yes
14	M	7,5	4.5	0.0	4.0	8.5	92	78	Yes	Yes	No	Yes	No
17	M	7,10	4.5	4.0	5.0	13.5	80	72	Yes	Yes	No	Yes	No
18	F	7,4	4.0	4.0	2.0	10.0	88	86	Yes	Yes	Yes	Yes	No
19	F	7,8	6.0	3.0	6.0	15.0	83	58	Yes	Yes	No	Yes	Yes
20	F	8,2	5.0	3.5	4.0	12.5	97	64	Yes	Yes	Yes	Yes	No
21	M	8,5	6.0	4.0	6.0	16.0	83	72	Yes	Yes	No	Yes	Yes
22	F	9,2	3.0	4.0	2.0	9.0	81	66	Yes	Yes	Yes	Yes	No
25	M	10,0	6.0	4.0	6.0	16.0	89	94	Yes	No	No	Yes	Yes
33	M	11,3	2.5	1.0	3.0	6.5	114	73	No	Yes	No	Yes	No

Chapter Five

DRAWING SKILLS OF CLUMSY CHILDREN

5.1 Introduction

It has been noted that difficulties with graphic tasks are extremely common among Clumsy children. This extends from the apparently simple task of drawing over a line to the highly complex sequences of movement required for free drawing and writing. In spite of the frequency with which such difficulties are recorded among these children, the amount of systematic investigation seems relatively small. This chapter comprises three studies which attempt to address a number of issues relating to their failure to develop skill in this area.

As noted in chapter two, a gap in the literature on this topic exists. Although there are some studies that have focused on the copying skills of Clumsy children, no detailed, objective data is available relating to their performance on less constrained drawing tasks.

In the first study in this chapter, childrens' attempts to draw a human figure are subjected to systematic scrutiny. Using the Goodenough-Harris 'Draw a Man' Test (Harris, 1963), the overall quality of the childrens' drawings are first compared to those of carefully matched controls of the same age and IQ. This analysis is then extended to provide much more detailed information on particular aspects of the childrens' drawing skill by sub-dividing the items into four groups each relating to a different aspect of performance (eg motor control, amount of detail) as proposed by O'Connor and Hermelin (1987).

The results of this cross sectional study produced age effects which were interesting but difficult to interpret, so a second study was designed which examined the drawing of a sub-set of the Clumsy children on a second occasion. Individual

differences in development of drawing skill are discussed.[1]

A general theme that runs through this thesis is that each task, or type of tasks is examined in two ways. First, purely descriptive data is collected, as described above. Second, the role of vision in performance is examined. This is the focus in the third of this series of studies. In this instance, the basic task is changed from figure drawing to shape copying and tracing. As mentioned in chapter three, there were several reasons for changing the task. The main reason being that it was decided to undertake an exact replication of the study undertaken by Lord and Hulme (1988). They employed a shape copying task in an investigation of the relationship between visual perception and motor competence, an issue that is desperately in need of further investigation. To do this a purely visual task was examined quite separately from the drawing tasks. The role of vision was also examined more generally by looking at the differences in performance with and without the aid of visual feedback information.

PART ONE

5.2 The Quality of Figure Drawing in Clumsy Children

5.2.1 Introduction
Free drawing is a common pastime for many young children. Drawing a human figure is a task which they are known to spontaneously attempt for themselves (Freeman, 1980) and one which has been studied by developmental psychologists in considerable depth (see eg Freeman, 1980 or Thomas and Silk, 1990 for reviews). In this exploratory study a human figure drawing task was employed to investigate the drawing skills of Clumsy children.

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[1]A version of the first two studies is published in the British Journal of Special Education, Vol. 62, 337-351 entitled 'Some observations of the figure drawing of Clumsy children' by Anna Barnett and Sheila E. Henderson

5.2.2 Method

Subjects: Two groups of 42 children, a Clumsy group and a control group, participated in this study. Details of the selection and characteristics of these children are provided in chapter four.

Procedure: Each child was asked to draw a picture of himself on a white sheet of paper using a pencil. The children were asked to draw a whole person and were encouraged to continue until they felt they had completed the drawing.

In order to assess the quality of the children's drawings, each one was scored using the Goodenough-Harris 'Draw a Man' Test (Harris, 1963). This involves examining individual features of the drawings and giving a score of 1 if the feature is present and/or correctly represented. Credits are then totalled and converted into standard scores (with a mean of 100 and a standard deviation of 15). A summary of the content of this assessment is shown in table 5.1. Also in this table, the subdivision of items into four sections, as proposed by O'Connor and Hermelin (1987) is indicated.

Although Harris (1963) describes the test as a way of measuring "intellectual maturity", in the present study it was employed purely as a means of obtaining some detailed and objective information on the quality of the childrens' drawings. In addition to using this scoring system, the size of the children's drawings were also measured. The drawings were scored by two independent raters, one of whom was blind as to the classification of the children as Clumsy or control. Inter-rater reliability was 92%.

5.2.3 Results

The characteristics of the children

The age, motor competence and intellectual capacity of the children are described in chapter four. Although both components of the WISC-R were administered when selecting the subjects, only the verbal component was used as a matching variable because the measure of cognitive ability it provides is uncontaminated by perceptual or motor difficulties. Since

Table 5.1. Summary of contents of Goodenough-Harris 'Draw a Man' Test (Harris, 1963) divided into four categories as proposed by O'Connor and Hermelin (1987)

Motor Control and Coordination

lines - firm, well-controlled
junctures - meet cleanly
Superior motor coordination - "bonus" point for good pencil
work on details and major lines
Directed lines and form - no obvious irregularities in:
head outline
trunk outline
arms and legs
facial features

Proportions

face - length greater than width
head I - area not more than 1/2 or greater than 1/10
that of trunk
head 11 - approx. 1/4 of trunk area
arms I - at least equal to trunk in length
arms II - arms taper
legs - length not less than vertical measurement of trunk
feet - shown in two dimensions
Trunk - shown in two dimensions
Limbs in two dimensions - both arms and legs shown in
two dimensions

Depiction of Features

Head	Hands
Neck	Wrist or ankle
Eyes	Arms
Nose	Shoulders
Mouth	Legs
Chin and forehead	Hip
Hair	Feet
Ears	Trunk
Fingers	Clothing

Detail in Features

Neck, two dimensions
Eye detail: brow or lashes
            pupil
            glance
Nose, two dimensions
Lips, two dimensions
Both nose and lips in two dimensions
Projection of chin shown
Line of jaw indicated
Bridge of nose
Hair details
Correct number of fingers shown
Detail of fingers correct
Opposition of thumb shown
Shoulders continuous with neck and arms
Arms at side or engaged in activity
Elbow joint shown
Hip detail
Knee joint shown
Feet: heel
Feet: perspective
Feet: detail indication shoe
Attachment of arm and legs to trunk
Clothing details

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the matching was done on an individual basis, the difference between the group means was small and not significant (t = 1.3). However, since the direction of the difference was in favour of the control children, the added precaution was taken of using analyses of covariance on all of the data which follows. None of these analyses indicated that verbal IQ was related to drawing performance, precluding the possibility that Clumsy children's drawing problems might be attributed to the sort of cognitive processes that are associated with verbal reasoning.

A global view of the children's drawings

To obtain a global view of the children's drawing performance, overall scores on the Goodenough-Harris test were first examined. A standard score for each child was determined from the manual as well as a 'drawing age', calculated in the same way as one would determine a mental age on an IQ test. Both of these measures are shown in table 5.2, along with the extent to which the children's 'drawing age' differed from their chronological age.

Table 5.2. Goodenough Harris Scores for the Clumsy and control children: a. Scaled Score b. Drawing age c. Delay in drawing (expressed in years).

		Clumsy	Control
a. Scaled Score:	mean	78.00	102.53 **
	SD	11.72	10.37
	range	50-102	80-125
b. Drawing Age:	mean	6.84	8.98 **
	SD	1.86	2.33
	range	2.8-11.3	4.4-14.6
c. Delay:	mean	-1.99	0.15 **
	SD	1.22	0.89
	range	-5.14-+0.20	-1.98-+1.66

** $p < .001$

As table 5.2 shows, the scaled scores for the Clumsy children were considerably lower than for the controls (F = 99.74; df = 1,78, p<.001) as were their 'drawing ages' (F = 19.04; df = 1,78 , p<.001). When these scores were then expressed in terms of "delay" in drawing ability it emerged that the Clumsy

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children were on average almost two years behind their peers (F=76.68, df=1,78, p<.001) with a range extending from approximately equal to five years behind.

In figure 5a, the difference between the Clumsy children and their controls is displayed on a subject by subject basis. In spite of the difference in overall level of performance, what the figure shows is that 'drawing age' and chronological age are correlated in both groups of children (.85 for the Clumsy group and .93 for the controls; p<.001 in each case). At the same time, however, there is a suggestion that some of the older Clumsy children might be further behind their age peers than the younger ones. A significant correlation between the **amount of delay** and chronological age within the Clumsy group supported this observation (r=.60, p<.001). The same correlation for the control group was only .24, these two correlations being significantly different from each other (p<.01).
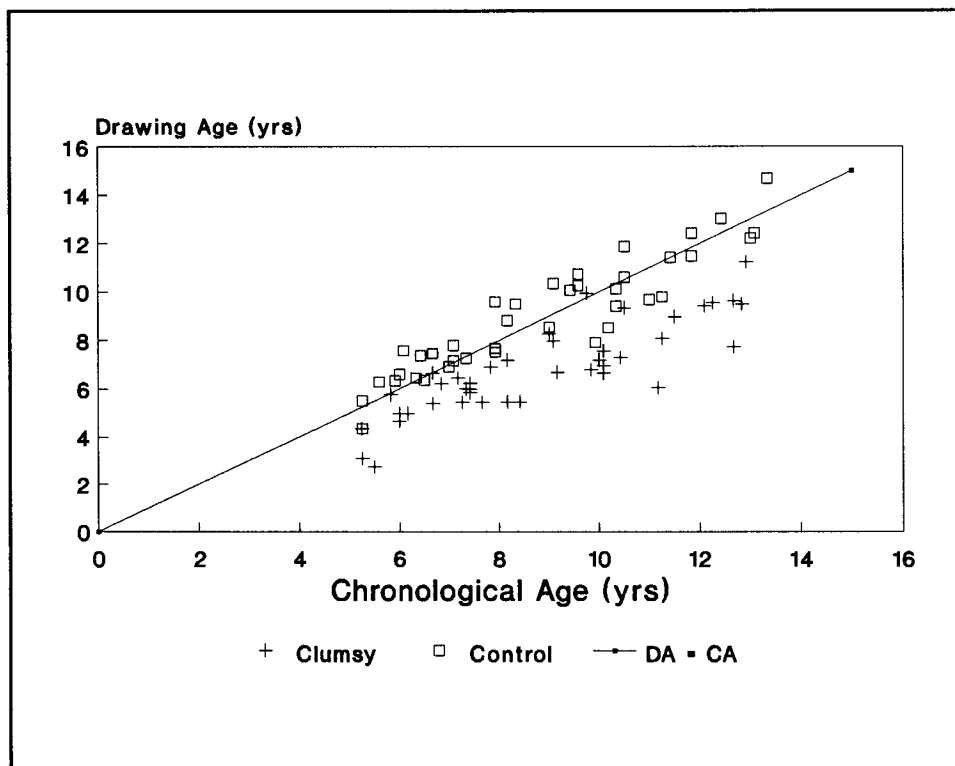
Figure 5a. The relationship between chronological age and drawing age for individual subjects

Overall size of the Drawings

Recently, investigators concerned with the process of drawing

have addressed the question of how children plan the spatial layout of their drawings (see Thomas and Silk, 1990, for a review). These investigations have included simple measures such as size comparisons as well as the analysis of more complex features. As nothing at all was known about how children with movement difficulties plan their drawings, an examination of the overall size of the figures produced was undertaken. A comparison between the groups indicated that the Clumsy children tended to draw smaller figures than their peers (mean height in mm 84.1 vs 97.8) but that the difference was not significant.

Drawing ability and the other measures

The children's drawing scores correlated significantly with their scores on both the TOMI (r=.78) and the performance component of the WISC-R (r=.72), which in turn correlated with each other (r=.68). A multiple regression analysis then revealed that as predictors of drawing ability these two tests accounted for 68% of the variance in drawing scores. Clearly, there is overlap between the WISC-R, the TOMI and the drawing task. Exactly what the nature of this overlap is, however, requires further investigation.

Four aspects of drawing ability

As noted above, the Goodenough Harris test was adapted by O'Connor and Hermelin (1987) in a way that suited the purposes of the present study very well. They sub-divided the items of the test into four groups, each intended to assess a qualitatively different aspect of performance. In exactly the same way as they had done, therefore, the drawings were re-analysed so that each one was given four sub-scores as well as an overall total. The four divisions were:

    (a)   Motor control and coordination

    (b)   Representation of proportions

    (c)   The depiction of particular features

    (d)   The awareness of detail in any feature

Since the total number of items for each category is different (see table 5.1), the raw data had first to be transformed into proportions and subjected to an arcsine transformation before analyses of variance could be performed without violation of

any of the critical assumptions (Winer, 1971). The scores obtained for each group of children are shown in figure 5b.

When these data were subjected to a two way analysis of covariance both the main effects of group and of category proved to be statistically significant (F=77.75, df=1,327, p<.001 and F=178.69, df=3,237, p<.001 respectively). Of particular interest, however, was the significant interaction between group and category (F=21.08, df= 3,237, p<.001). Although the two groups differed significantly on all four categories, post hoc analysis using Tukey's procedure revealed that by far the largest difference was in the section containing items related to motor control and coordination.

The differences between the groups on the four categories are illustrated in figure 5c. In each case, a drawing by a Clumsy child is shown on the left with a drawing by their matched control on the right.

a. Ability in motor control and coordination
The drawings done by the Clumsy children were characterised by irregular, poorly controlled lines which, for some subjects resulted from observable tremor. Shapes were often incomplete because the child had missed the target end point (for example, when drawing a circle for the head or eyes). Often lines did not meet cleanly at junctures, with a marked tendency to overlap or leave an intervening space (see drawing A). Shading was inaccurate and variable, indicating poor control of force.

b. Ability to represent proportions correctly
In this category, the Goodenough-Harris test includes items such as "area of head not more than 1/2 or less than 1/10 that of trunk" and "arms at least equal to trunk in length". Drawings C and D illustrate the difference between the groups when rated on this set of items.

As noted above, experimental analyses of children's drawings have included direct measurement of things like the representation of proportion in figure drawing (eg Thomas and
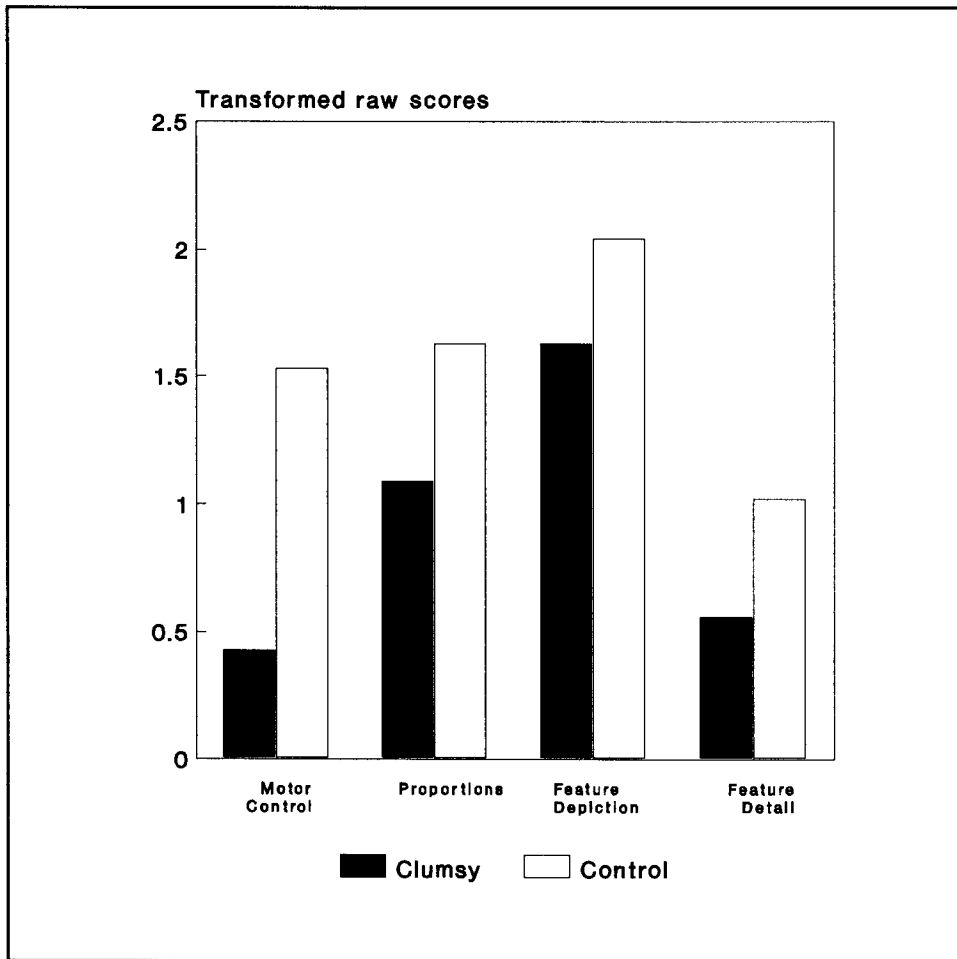
Figure 5b. Scores for the Clumsy and control children on four components of drawing ability.

Figure 5c. Drawings illustrating the difference between Clumsy children and their controls.

Clumsy Children

A
CA: 8 yrs, 1 mo
VIQ: 97

Control Children
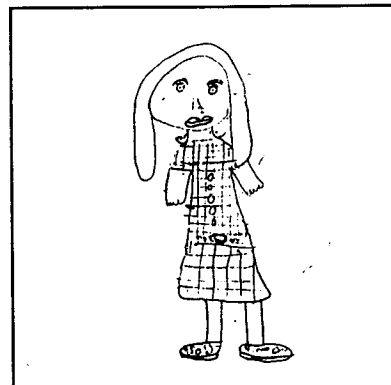
B
CA: 8 yrs, 3 mo
VIQ: 117
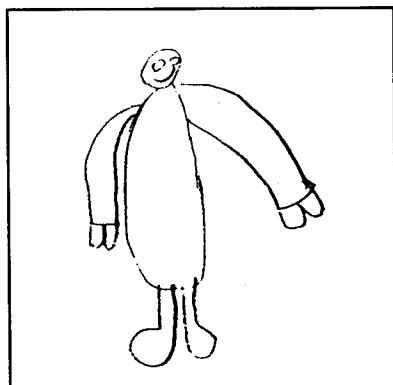
C
CA: 7 yrs, 4 mo
VIQ: 97
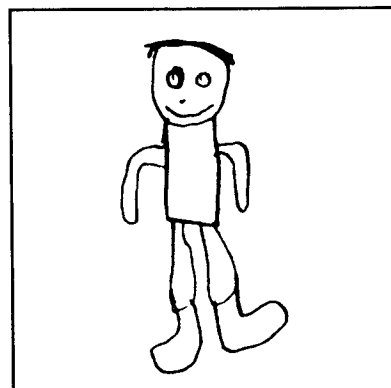
D
CA: 7 yrs, 0 mo
VIQ: 106

E
CA: 8 yrs, 1 mo
VIQ: 86
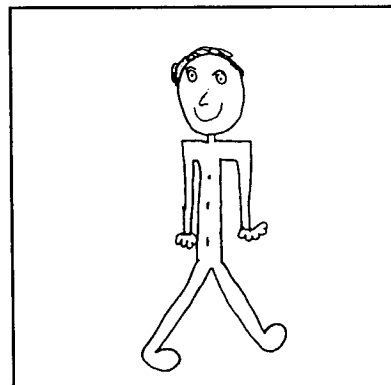
F
CA: 7 yrs, 11 mo
VIQ: 97

Tsalimi, 1988). Of particular concern has been the ratio of head to body size, which in very young children is often heavily weighted towards the head. When the proportion of head to trunk size was measured in this study, there was a slight tendency for the children with difficulties to make the head relatively large in comparison to the trunk (48% as opposed to 42% of body length) but the difference between the groups was not statistically significant. Where they seemed to differ more was in organising the proportions of the trunk and the four limbs.

c. Depiction of features and provision of detail

On these two components of O'Connor and Hermelin's rating system, the Clumsy children had more difficulty both in depicting particular features and providing detail within a feature (see drawings E and F). These categories contain items such as "eyes present" and "eye lashes shown".

Individual differences between the children

It is generally acknowledged that Clumsy children vary in the type and range of motor skills that they find hard to perform. Initial inspection of their drawings suggested that this skill was no exception. Since the group analyses presented above do not allow for any conclusions to be drawn about such individual differences, further analyses were undertaken.

Firstly, all of the children, both Clumsy and control, were classified as 'good' or 'poor' draughtsmen. As there is no generally accepted means of classifying children in this way the decision made had to be somewhat arbitrary. To be classified as a 'good' draughtsman, a child's "drawing age" had to be within one year of their chronological age, or above. All other children were considered to be 'poor' draughtsmen. Using this classification system, 36 of the control children and 9 Clumsy children were designated "good" drawers, and 4 control and 32 Clumsy children designated "poor" drawers (two children who only drew heads had to be excluded from this analysis).

With the children re-divided in this way, the profiles of their sub-scores were then examined. In order to be able to quantify the extent to which individuals varied on each of the four dimensions, the means and standard deviations of the control group were used as a reference. Individual drawings were rated as 'poor' on a component if they scored one standard deviation or more below the control mean.

a. The "good" draughtsmen

When the drawing profiles of the 45 children in this group were examined, an interesting contrast emerged. Whereas the overall scores of the control children were achieved by obtaining consistently even scores across all four dimensions, this was true of only one Clumsy child. All of the other Clumsy children obtained low scores on the motor control items and therefore, only achieved their good overall scores by compensation ie by producing well proportioned drawings with adequate detail. Consider, for example, drawing A in figure 5c. The lines are poorly controlled and inconsistent, some forms are not completed accurately (eg circles for the eyes) and lines tend to overlap at juncture points (eg where the arms are attached to the body). Yet in other respects the drawing is good. Elementary body parts are present with correct overall proportions, detail is given with shoes, wrists and hair and it is generally well organised.

b. The "poor" draughtsmen

As might be expected, the majority of these children were originally classified as Clumsy. For sixteen of these children their poor motor control was part of a consistently poor profile. The remaining Clumsy children and the controls in this group exhibited a variety of different profiles.

Among the Clumsy children in this category, there were two individuals whose drawings could only be described as bizarre. In particular, both drawings combined mature and immature features. For example, drawing C in figure 5e has not progressed beyond the 'stick man' stage yet some aspects seem more mature, such as the depiction of fingers and detail in the eyes.

5.2.4 Discussion

In the clinical literature it has often been noted that children labelled Clumsy are poor at free drawing people, houses and cars etc.. However, no norm referenced measure of performance has previously been used. Using the Goodenough-Harris 'Draw a Man' test as a measure of drawing ability, this study has demonstrated that such children are on average two years behind their peers in their ability to draw a human figure. This could not have been because the Clumsy children were intellectually less able then the well coordinated children as every precaution was taken to ensure that any differences that did exist were taken account of.

In addition to the general, and not very surprising finding that children with motor difficulties are poor at drawing, two aspects of the findings seemed worthy of further investigation. The first concerns the pattern of development in drawing ability with age in the Clumsy children. Although there was a general trend within the group for improvement with age, at the same time there was a suggestion that at least some children might not progress. This suggestion emerged from the finding that amount of "delay" in drawing age correlated significantly with chronological age for the Clumsy children but not for the controls ie some of the older children with difficulties were more delayed than the younger ones. With data from a single point in time, it is not possible to distinguish two different explanations of this finding. The first is that Clumsy children do fall farther and farther behind their peers as they get older. The second is that in this particular sample of Clumsy children the older ones just happened to be much worse at drawing than the younger ones.

The other finding that invites further investigation concerns the profiles of performance in the Clumsy group. From the total sample of forty two Clumsy children, 39 were classified as 'poor' on the component O'Connor and Hermelin designated "Motor Control and Coordination". In contrast, there was considerable variation on the other components. (There is no possibility that this outcome could be due to tester bias

because all of the drawings were scored by an independent observer, unaware of the children's status in the study.) The question of interest in this case is whether such a profile is a permanent feature of these children's performance or whether it is susceptible to change over time.

In the study that follows an attempt is made to investigate these two questions by re-examining the drawing skill of sixteen of the Clumsy children after a period of 18 months. For various reasons, it was not possible to test all of the children or to select a particular sub-sample. However, the children involved spanned a similar age range to that covered before and varied in the extent to which they were judged to be behind their peers.

5.3 What does happen as children get older? - a Longitudinal Analysis

5.3.1 Method

Subjects: For various reasons, it was not possible to retest all of the Clumsy children who participated in the original study. Since the norms for the Goodenough Harris test had proved satisfactory in the first study, it was not considered imperative to follow up children from the control group.

The characteristics of the sixteen children who participated in this study are given in table 4.6 in chapter four. At the time of the follow up they ranged in age from 7.1 years to 12.8 years, had verbal IQ's of between 80 and 123, performance IQs between 58 and 106, and TOMI scores of between 4.5 and 16.

Procedure: The children were again seen individually and the procedure was identical to that described above.

5.3.2 Results

Table 5.3 shows the mean scores for this group of subjects on first and second testing. On average the children improved their drawing performance significantly over the eighteen month period (t = 4.51, df = 14, p<.05) but once again there was considerable variation between individuals in the extent

Table 5.3. Goodenough-Harris scores in original and follow up studies.

		Original Study	Follow Up Study
Scaled Score:	Mean	75.73	88.40 **
	SD	12.68	15.75
	range	50-99	69-123
Drawing Age:	mean	5.63	7.99 **
	SD	1.31	1.65
	range	2.75-7.2	5.06-10.97
Delay:	mean	-1.78	-1.13 **
	SD	0.89	1.48
	range	-2.95 - -0.06	-3.02 - +2.05

** $p < .05$
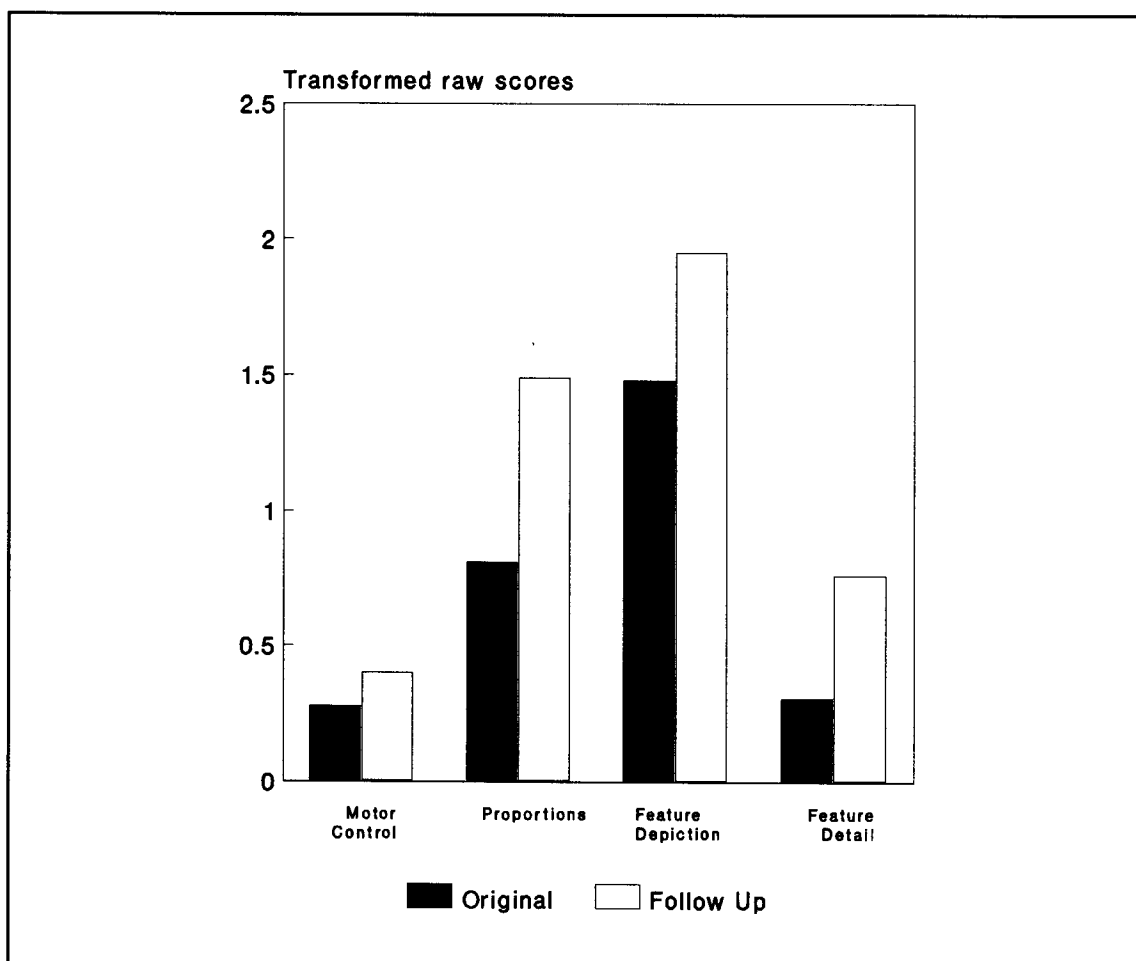
Figure 5d. Changes in the profiles of the 16 Clumsy children over an 18 month period

to which their scores deviated from being age appropriate.

In figure 5d, the change in the children's scores on each of the four components of performance over time is presented. When these scores were subjected to a two-way analysis of variance both the main effect of 'passage of time' and of category were found to be significant (F = 47.0; df 1,14, p< .001; and F = 89.62; df 3,42, p < .001, respectively). The interaction between 'time' and the four drawing components was also significant (F = 6.67, df 3,42, p < .001). Post hoc analyses using Tukey's procedure revealed that this was explained by the difference between test and retest being significant for all of the components except Motor control and Coordination.

Individual differences within the group
The sixteen children participating in this part of the study included twelve whose drawings were considered to be substantially delayed when they were first tested and four whose drawings were more nearly age appropriate. In figure 5e, two examples of the changes in performance exhibited by these children are shown.

Of the twelve children whose drawing ages had been considerably delayed in the original study, eight continued to lag behind their peers. The extent of their delay extended to four years and for three children this represented a notable deterioration in performance level. For example, drawing A in figure 5e was scored as being delayed by 2 years 2 months. Eighteen months later the same child's drawing was scored as being 2 years 8 months behind (drawing B).

It is also essential to note, however, that four children had made progress to the extent that they were now within one year of producing age appropriate drawings and that the four children who had originally met this criterion had maintained the same level of performance. Even within this subgroup, however, only one child actually improved on the component motor control and coordination.

Figure 5e. Drawings illustrating the performance of Clumsy
children over an eighteen month period

Original Study

A
CA: 7 yrs, 8 mo
VIQ: 83

C
CA: 10 yrs, 0 mo
VIQ: 89
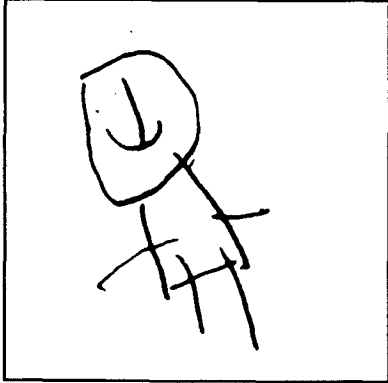
Follow-up Study

B
CA: 9 yrs, 4 mo
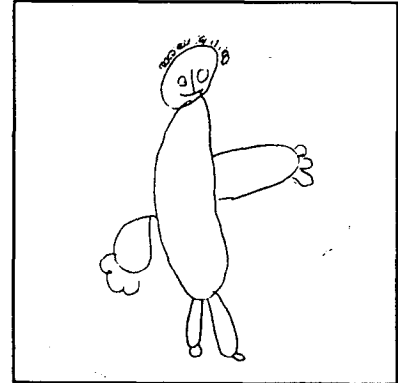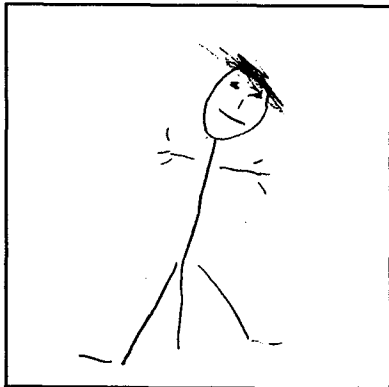
D
CA: 11 yrs, 7 mo
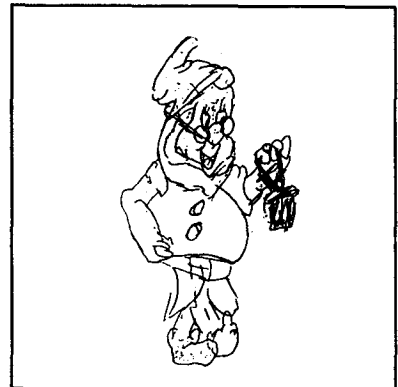
E

Improvement in drawing ability was particularly striking for one child (figure 5e, drawings C, D and E). Within the eighteen month period, his figure drawing had progressed from the 'stick man' stage to a level that was both highly competent and sophisticated. Although some of the proportions are still poor and it is apparent that he continues to have poor control of his pencil, the amount of detail and number of features depicted has increased substantially.

An interesting aspect of this boy's performance were the strategies which he had acquired to enable him to overcome his motor control problems. In drawing the figure's legs he used a 'sketching' technique, thus preventing the longest lines in the drawing from appearing wobbly. In the face, he managed to produce clarity and detail in the features such as the nose, mouth and ears by pressing hard on the paper with his pencil and, at times, using his non-drawing hand to help guide the instrument. Drawing E in figure 5e was not collected as part of this study but is shown here to illustrate the extent of this boy's improvement.

5.4 General Discussion

As discussed in chapter one, clumsiness is a developmental disorder which is difficult to delineate. The many different words and phrases that are used as labels, not only represent differences in professional terminology, they also represent fundamental differences of opinion on the nature of the problem. For example, the apparently simple phrase "motor delay" implies something quite different from the term "developmental agnosia and apraxia" (Gubbay, 1975). Whereas the first seems to imply a rather benign condition which will disappear over time the second implies a condition which mirrors one that occurs in adults with known and irreversible brain damage. The opposition of these two alternatives will be recognisable as the "delay versus different or deviant" debate so common in childhood disorders generally.

The findings in these two studies contribute a little to this debate. Beginning first with the overall scores on the 'Draw A Man' test, it has certainly shown that Clumsy children's

drawing is delayed in comparison to that of well coordinated
children of the same age and verbal ability. Moreover, the
more Clumsy a child is generally, the worse their drawing.
When both Performance IQ and TOMI scores were entered into a
multiple regression analysis, 68% of the variance in drawing
performance was accounted for.

By examining the 'drawing ages' of these children in relation
to their chronological age in more detail, however, it became
clear that the developmental pathway they follow is not
captured very accurately by the simple notion of delay. In the
first study, for example, it was found that some of the older
Clumsy children seemed to be much more delayed than the
younger ones, a finding pursued by exploring some of the
childrens' development over an 18 month period. Although the
follow up study was limited in that the sample size was rather
small and involved only one repetition of the task, the
results nevertheless revealed that there were indeed some
children who continued to fall farther and farther behind
their peers (although others improved).

The finding that most of the children in the sample had not
caught up with their peers is consistent with two recent
clinical studies which have examined the long term prognosis
for children labelled Clumsy. (Gillberg et al, 1989; Losse et
al, 1991). Both of these studies found that many Clumsy
children continue to have motor difficulties well into their
teenage years and do not just "grow out of it".

When the four different aspects of figure drawing was examined
it was found that the Clumsy children were not just worse than
controls in terms of motor control and coordination, but that
they were initially inferior in all aspects - the
representation of proportions, feature depiction and feature
detail. It is not at all obvious why, if one has difficulty
drawing a circle for a head, one does not add a nose. A rather
simplistic explanation of this outcome might be that these
children simply don't draw very much and are, therefore,
delayed in all aspects of their performance. However, such an
explanation does not account for either the existence of

Clumsy children whose drawing is good in spite of "motor control" difficulties or the fact that the children in the follow up study improved on all of these aspects of performance except motor control.

The follow up study showed that no child who had obtained a poor rating in the category of motor control had improved. However, the group results revealed improvements in the other aspects of figure drawing skill such as the depiction of features and the representation of proportion. Several cross sectional studies in the literature describe similar difficulties in Clumsy children (eg Lord and Hulme, 1988; Hulstijn and Mulder, 1986) but none which have shown this persistence over time alongside improvement in other dimensions of drawing.

Among the children who actually improved their drawing skill, one in particular is worthy of further mention. This child's drawings are depicted in C, D and E of figure 5e. The remarkable change in his drawing skill serves to illustrate the extent to which factors other than those central to the core problem can affect progress. In this instance, motivation seemed to lead to the development of compensatory strategies in drawing which were denied other children who were similarly impaired. Despite the fact that it was still possible to detect evidence of poor motor control in his drawing, he had found ways round this which made his difficulty almost imperceptible to the lay person. Obviously practice, too, must have played a part in his improvement, as he drew Disneyland figures like that shown in E (figure 5e) almost obsessively but it seems that practice was not the primary cause. Many of the other children in the sample practised drawing but they did not improve to the same extent.

When other individual results from the follow up study were examined, it was found that there were 8 Clumsy children who did not improve in any aspects of drawing performance. That is, in addition to motor control problems, they continued to have difficulties with the representation of proportion and depiction of detailed features. One explanation for the

failure of some children to improve on these aspects of drawing performance relates to their visual perceptual skills. If, as reported by Hulme and colleagues (Hulme et al., 1982; 1984), some Clumsy children have poor visual perceptual abilities, then these may cause poor performance in these categories. In the next section an experimental approach is taken to examine the relationship between visual perceptual ability and drawing performance.

5.5 Do visual perceptual problems cause clumsiness? - another look at this hypothesis

5.5.1 Introduction

From the two studies described in part one, a number of interesting findings emerged concerning the problems Clumsy children experience in drawing a human figure. There was evidence that they had problems with the most basic aspects of motor control, producing shaky lines and being unable to make lines meet neatly. At the same time, however, it was clear that other problems the children experienced, such as the poor representation of proportion, were more to do with the spatial characteristics of movement.

In terms of the latter difficulties, one possible explanation is that these children have visual perceptual problems. Taking this view, it may be the case either that these children do not see the world as we do or that they cannot translate visual perceptual information into graphic output.

Since part one of this chapter was purely descriptive in nature, it was not possible to explore the question of whether visual perceptual problems might actually be a determinant of drawing difficulties. To investigate this question therefore, we need to turn to the experimental approach.

As noted at several points throughout this thesis, the idea that visual perceptual problems might be a major determinant of clumsiness in children has been pursued at length by Hulme and colleagues (Hulme et al., 1982; 1984) but for various reasons requires further investigation. One of their series of studies used a drawing task and pursued the question of the relationship between visual processing and motor competence in two ways. In order to perform a detailed examination of this issue in relation to drawing skills, a decision was made to employ a replication of the study.

The study to be replicated was that of Lord and Hulme (1988), in which the children were required to perform a visual discrimination task that was a pure test of perceptual ability. They also performed tracing and shape copying tasks which, when added to the data on human figure drawing provides a way of generalising across the graphic domain. As previously mentioned, perceptual skills and motor competence were investigated in two different ways in this study. Firstly, a correlational approach was used to examine the relationship between performance on the purely visual task and performance on the drawing tasks. Secondly, visual feedback information was removed during copying performance which, as described in chapter two, provides a means of investigating the role of vision in drawing performance.

5.5.2 Method

Subjects: Two groups of 16 children, a Clumsy group and a control group, participated in this study. Details of the selection of these children are described in chapter four with details of the 16 Clumsy children provided in table 4.6.

Procedure: Each child was tested individually.
The Visual Discrimination Task: The stimulus material for this task consisted of a series of 32 white cards, each 15cm by 26cm on which pairs of triangles were drawn, one above the other, separated by a transverse black line. On 16 cards both triangles were equilateral with sides 70mm long. On the other 16, the size and shape of the upper triangle was held constant while the lower one varied. To achieve variation in the lower triangle, the length of two sides stayed the same and the base changed from 46 to 94mm in 3mm steps.

The discrimination task was presented as follows. Cards were held up one at a time in front of the child in random order, at a viewing distance of 60cm. The child's task was to say whether the two triangles on each card were the same or different. A few initial practice trials with feedback were given to ensure that the children fully understood the task. In the test trials proper, no feedback was given.

Each child completed a sequence of three drawing tasks. Order of presentation was balanced according to a Latin square.

Tracing. Subjects were presented with two line drawings of equilateral triangles, and were required to trace over them as carefully as possible.

Copying with visual feedback (V-VK condition). Subjects were presented with a single equilateral triangle (of sides 70mm as before) and were asked to reproduce it on a sheet of A4 paper. They were instructed to make their copy the same size and shape as the one on the card. The stimulus card remained present throughout the trial. Two attempts were given.

Copying without visual feedback (V-K condition). In this case, the child's task was identical to that described above except that sight of the hand and the graphic output was occluded by placing a large box over the arms. The box did not interfere with the drawing action in any way. As before, the stimulus triangle remained visible.

5.5.3 Results
Comparability of the samples in the two studies
Table 5.4 shows the characteristics of the children in the present study together with those of the children studied by Lord and Hulme (1988). The children from the two studies neither differed significantly in age (Critical Ratio=1.25), nor on verbal IQ, although the tendency towards lower verbal IQ in our study just failed to attain significance (Critical Ratio=1.94). Moreover, in neither study was the difference between the motor impaired children and the control groups significant (Age: both Fs <1; IQ: F=3.36 in the present study; F=2.08 in the original, p_{min}>.10).

In both studies, the contrast in motor competence between Clumsy and control groups seemed highly robust across all measures. On the criterion measures used to select subjects, Lord and Hulme (1988) found their Clumsy group to be significantly inferior to controls on each of their five tasks. Likewise, in the present study, the groups differed

significantly on each of the eight component test items from the TOMI ($p_{min} < .01$).

Table 5.4. Age and IQ scores for the subjects in the replication and the original study.

		Clumsy	Control
Chronological Age (yrs)			
Present study:	mean	7.65	7.64 ns
	SD	0.41	0.41
Lord and Hulme:	mean	9.87	9.82 ns
	SD	1.34	1.32
Verbal IQ			
Present study:	mean	95.80	102.20 ns
	SD	14.43	10.82
Lord and Hulme:	mean	106.26	114.58 ns
	SD	18.31	17.18
Performance IQ			
Present study:	mean	79.60	104.90 **
	SD	16.02	15.50
Lord and Hulme:	mean	83.37	113.21 **
	SD	20.89	20.46

** $p < .001$

Performance on the Visual Discrimination Task

As in Lord and Hulme's study, the children's same/different responses on this task were converted to d prime (d') discriminability values (Green and Swets, 1966). These values express, in standard deviation units, the discriminative sensitivity of the subjects as reflected in their same/different judgements. A d' value of zero corresponds to chance performance and indicates that the subject is unable to differentiate between stimuli, whereas a score of 3.0 corresponds to near perfect performance.

From table 5.5, it can be seen that the d' values obtained in the present study were remarkably similar to those reported by Lord and Hulme. It was found, as they had done, that the Clumsy group were significantly less sensitive than the controls on the triangle discrimination task ($F=16.43$, $df= 1,30$, $p < .001$).

Table 5.5. D Prime scores for the visual discrimination task.

		Clumsy	Control
Present study:	mean	1.33	2.18 **
	SD	0.60	0.58
Lord and Hulme:	mean	1.19	2.03 *
	SD	0.98	1.37

** p<.001   * p<.05

Performance on the drawing tasks
Tracing

Our Clumsy group were significantly poorer than controls at tracing (F=51.74, df=1,30, p<.001), echoing the significant differences reported by Lord and Hulme.

Copying with and without visual feedback

Figure 5f shows some examples of children's copying with and without visual feedback. Lord and Hulme employed two measures of the accuracy with which the triangular forms were copied, one reflecting errors of size, the other, errors of shape. Wherever in the child's graphic output the two sides of a triangle did not meet or the lines were not straight (see figure 5f for examples) the accuracy measures could not be calculated until the distorted side had been replaced by a "line of best fit", derived from the child's copy. Once this had been done, a measure of the accuracy of SHAPE depiction was obtained by measuring in degrees the three angles enclosed by the best fit lines, determining the difference of each value from 60 and calculating the mean of these three differences.

A measure of the accuracy of SIZE depiction was obtained, exactly as in Lord and Hulme, by measuring the length of each of the sides in the child's copy, calculating the deviation from the length of the stimulus and summing these deviations regardless of sign. This yielded a measure of <u>absolute error</u> but did not reflect any directional tendency in the error. The absolute error measure was therefore supplemented with a measure of <u>constant error</u>, in which the summation across sides

Figure 5f. Examples from four Clumsy children of copying triangles with and without visual feedback of the hand.

WITH VISUAL FEEDBACK
(V-VK)

WITHOUT VISUAL FEEDBACK
(V-K)

A

B

C

D
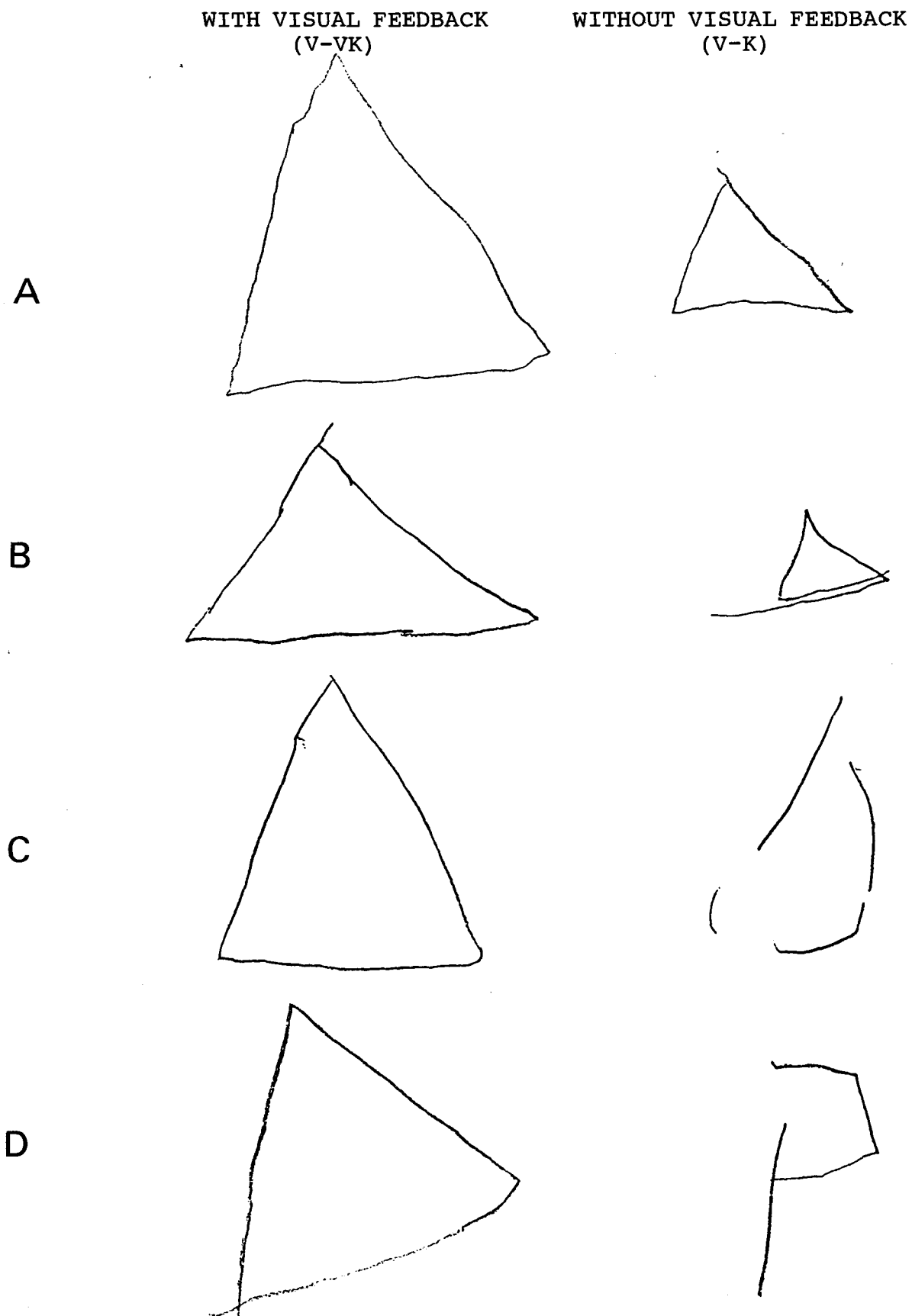
preserved the sign of each difference. This provided a measure
of overall bias towards drawing the triangle smaller or larger
than the stimulus, according to whether the measure is
negative or positive, respectively. The results from both
studies are shown in table 5.6.

As far as reproducing the SHAPE of the triangle was concerned,
analysis of variance revealed that the Clumsy children did
this significantly less accurately than the controls (F=6.40,
df=1,30, p<.02). Lord and Hulme's results were identical in
this respect (F=6.01, p<.05). In the replication the absolute
error in copying SIZE information also distinguished
significantly between the groups (F=7.28, df=1,30, p<.01). In
this case, however, Lord and Hulme did not find significant
group differences. In the case of constant error, the
difference between the two groups was not significant (F<1).
The results of the analysis for the two feedback conditions
are given on page 141.

Table 5.6. Errors for copying with visual feedback (V-VK) and
without visual feedback (V-K) from both studies

Type of Error		Clumsy		Control	
		V-VK	V-K	V-VK	V-K
Shape Errors (AE)					
Present study:	mean	11.65	13.00	6.42	8.29
	SD	8.88	5.74	4.51	4.51
Lord and Hulme:	mean	10.26	12.98	5.58	8.90
	SD	6.83	6.28	4.24	6.35
Size Errors (AE)					
Present study:	mean	20.95	33.32	12.82	20.94
	SD	13.33	14.02	11.19	8.71
Lord and Hulme:	mean	16.56	27.59	12.53	24.49
	SD	7.76	12.04	8.77	10.08
Size Errors (CE)					
Present study:	mean	-8.70	-22.76	-9.49	-9.81
	SD	21.55	26.44	13.78	20.14
Lord and Hulme:	mean	-	-	-	-
	SD	-	-	-	-

- data not reported

Figure drawing

In addition to the figure copying and tracing measures, the measures taken from figure drawing reported in part one of this chapter were also available. The Clumsy children produced figure drawings that were rated as significantly less mature than those of the controls (F= 45.75, df=1,30, p<.001). When a measure of delay was determined using the scoring system of the Goodenough Harris test, the Clumsy children were judged to be up to three years behind their matched controls (F=45.75, df=1,30, p<.001).

Agreement amongst the measures of motor coordination

Table 5.7 displays the inter-correlations between performance on the tasks which have a substantial motor competence component (TOMI, figure drawing, tracing, copying errors for shape and size). These correlations are for the entire data set combined across groups. As a simplification, the only performance measure considered for copying is absolute error. Given the differences between the tasks, there is, in general, remarkably good agreement between the measures.

Table 5.7. Inter-correlations between different measures of motor competence.

	TOMI	Human Figure Drawing	Tracing	Copying shape (V-VK)	Copying size (V-VK)
TOMI		.84 **	.84 **	.32	.35
Human Figure drawing			.75 **	.37	.53 *
Tracing				.50 *	.38

  * p<.05
  ** p<.001

Relationship between visual discrimination and the motor performance measures

In table 5.8 the correlations between performance on the visual discrimination task and copying, tracing, figure drawing and TOMI scores are presented for all 32 subjects taken together and for each group, separately. In the replication study only two of these correlations are

significant, those involving TOMI (p<.001) and human figure drawing (p<.01). Both of these are for the full data set resulting from combination of the groups. Inspection of the correlograms (Figures 5g a,b) for these two, reinforced the conclusion suggested by the coefficients. **Within** either group, there was no hint of a linear relationship between visual discriminative performance and either TOMI or human figure drawing. The significant correlations are entirely due to differences in visual discrimination **between** the groups, hence their emergence only when the groups are combined.

Table 5.8. Correlations between visual discrimination ability (d prime) and motor measures.

	Clumsy	Control	All
Shape Errors (V-VK) Present study Lord and Hulme	-.01 -.52 *	-.06 .10	-.22 -
Shape Errors (V-K) Present study Lord and Hulme	-.16 -.30	-.16 .06	-.37 -
Size Errors (V-VK) Present study Lord and Hulme	-.21 -	-.11 -	-.24 -
Size Errors (V-K) Present study Lord and Hulme	.19 -	.00 -	-.21 -
Tracing Errors Present Study Lord and Hulme	.29 -.55 **	.25 .12	-.35 -
General Motor Competence Present Study (TOMI) Lord and Hulme	-.15 -	-.01 -	-.56*** -
Figure Drawing Present Study	.15	-.15	.47**

*   p<.05
**   p<.01
***   p<.001

-     correlation not reported
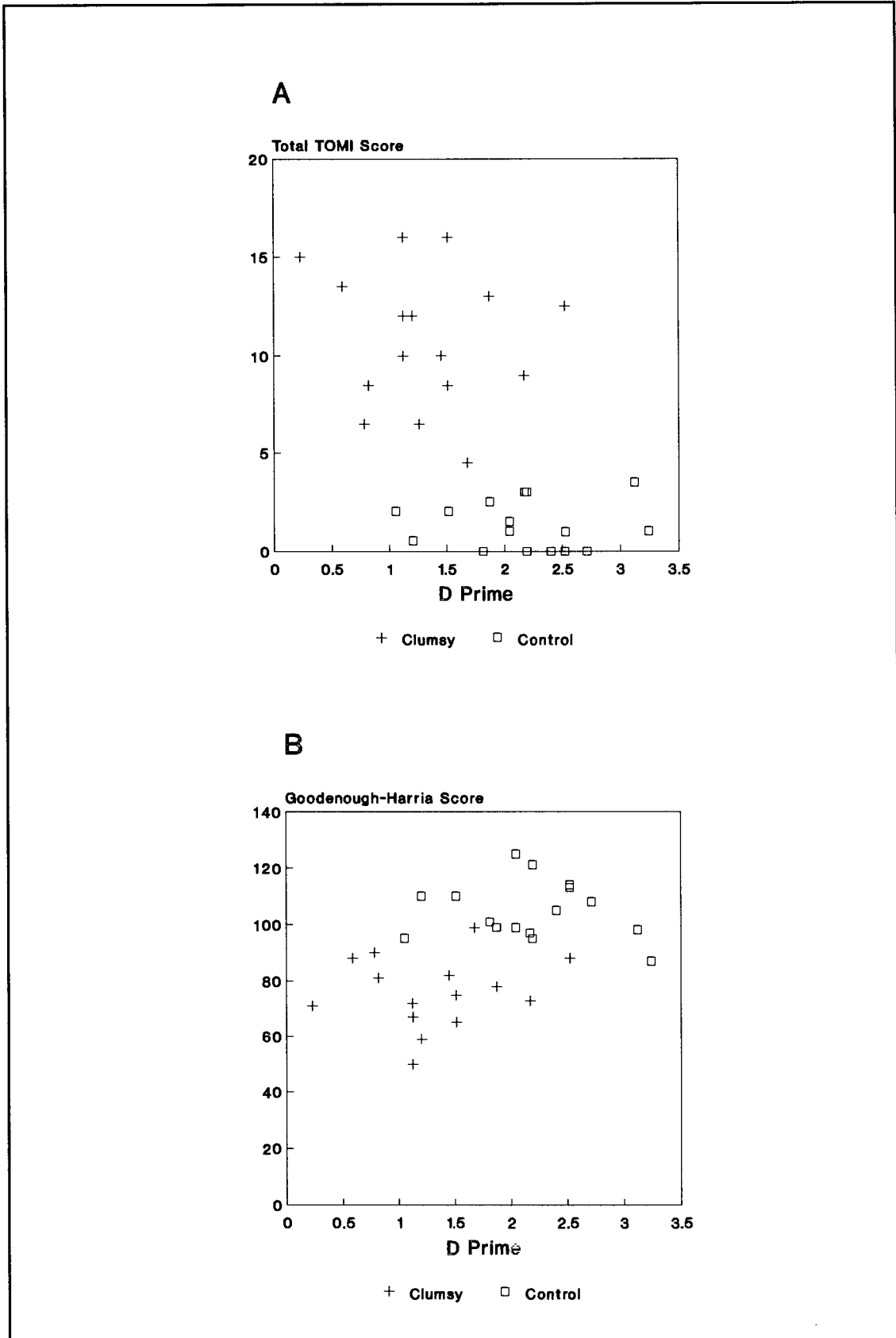
Figure 5g. Scatterplots illustrating the relationship between A. d' and total TOMI scores and B. d' and Goodenough Harris drawing scores

Manipulation of visual feedback information

The results for drawing with and without visual feedback are shown in figure 5h. As reported earlier, the Clumsy children were generally less accurate at reproducing shape than the controls. While there was a marginal tendency for shape accuracy to be poorer in the absence of visual feedback (F=2.89, df=1,30, p<.10) the lack of any tendency towards interaction (F<1) suggested that the two groups did not differ in the extent of their reliance on visual feedback. These results are similar to those of Lord and Hulme (1988).

The Clumsy children were also worse at reproducing the size of triangles. In this case, performance was significantly worse in the absence of visual feedback (F= 29.68, df= 1,30, p<.001) but once again this effect showed no tendency to interact with the group factor (F=1.28 ns).

When the effect of removing visual feedback was pursued using the constant error scores, however, a different picture emerged (see Figure 5h C). In this case, the error was generally no greater for the Clumsy group (F<1). However, there was a significant tendency to draw smaller shapes when copying without visual feedback (F=5.42, df=1,30, p<.05) and a significant group by feedback condition interaction indicated that this tendency was much greater in the Clumsy group (F=4.94, df=1,30, p<.03). The examples in figure 5f illustrate the effect of removing visual feedback information on performance.

Although most of the Clumsy children did perform more poorly when vision was not available to guide their movements, the group results do mask some interesting individual differences. For example, there was one child in the Clumsy group whose drawing performance was better when visual feedback was not available. When he could not see his hands, he drew larger triangles (by about 3cm.) that resembled both the size and shape of the stimulus more closely.

A. Shape Errors (AE)

Absolute Error (degrees)

Group

■ Clumsy ☐ Control

B. Size Errors (AE)

Absolute Error (mm)

Group

■ Clumsy ☐ Control

C. Size Errors (CE)

Constant Error (mm)

Group
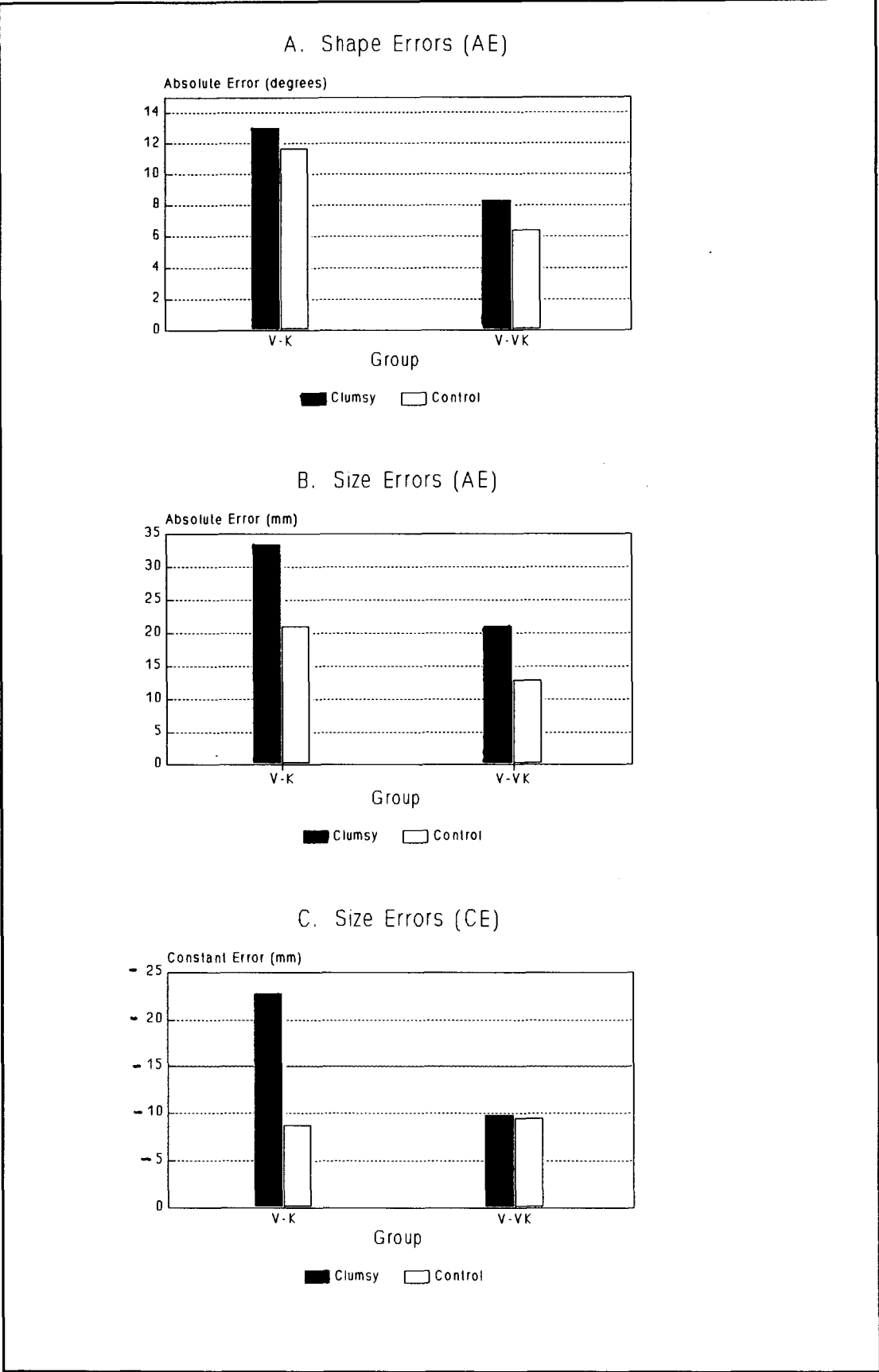
■ Clumsy ☐ Control

Figure 5h. Errors in figure copying task for Clumsy and control children in V-K and V-VK conditions.

5.5.4 Discussion

The present investigation took the form of a replication of a previously published study. This was undertaken for several reasons. The first of these was to examine the claim that Clumsy children have visual perceptual problems. Secondly, it allowed for the examination of a different set of drawing skills, adding to the data collected in part one. Thirdly, the relationship between visual perceptual ability and motor competence could be examined in relation to a range of motor tasks. Finally, this study allowed for a preliminary examination of the role of vision in manual performance. These four issues are discussed in the following discussion of the results.

Do Clumsy children really have problems of visual perception?
The first concern is whether Clumsy children do have problems of visual perception. As in Lord and Hulme's study, it was found that the Clumsy children performed significantly more poorly than controls on the visual discrimination task. Recently, Powell and Bishop (1992) have reported similar findings in a study involving 17 children whose primary problem was one of language development. Also, Hoare (1991) has provided a further replication of the outcome on 80 Clumsy children. Taking the group results of all of the studies involving the same kinds of visual discrimination tasks together, there seems to be little doubt that visual perceptual difficulties are indeed present in children commonly described as Clumsy. However, in the present study it was found that the group differences masked enormous individual differences in the Clumsy group. Whereas some Clumsy children were clearly having severe difficulty with the visual discrimination tasks, others were indistinguishable from the controls.

Consistency of performance in the drawing domain
The second issue concerns the consistency of performance of Clumsy children in the drawing domain. As in Lord and Hulme's study, the results of the present study have shown that, compared to matched controls, Clumsy children are impaired in drawing tasks requiring the tracing and copying of simple

shapes. This now complements the findings of the previous study showing that Clumsy children are significantly worse at drawing a human figure. All of these tasks involve the controlled manipulation of the pencil to produce lines on paper. Beyond this, however, they differ quite considerably. The tracing task may be described as involving the most direct graphic response, as it is mapped straight onto the stimulus. The copying task involves a greater perceptual component, requiring the child to make perceptual judgements concerning the stimulus and then to transfer this visual perceptual information into a graphic response. The task allows continuous monitoring of the stimulus and (in the V-VK condition) the outcome, allowing for error detection and correction. In contrast, no stimulus is provided in the figure drawing task to guide performance. In this task the child has to decide and plan what to draw according to what he himself considers to be the characteristics of a human figure. In this task there is no stimulus to constrain performance, except what the child draws himself (for example, if the head is drawn first, it's size and position may be used to guide subsequent drawing of the trunk). Despite these task differences there is remarkable agreement between the performance measures, as was shown by the correlations between them. This points to the consistency of performance in this area of manual functioning.

The relationship between visual perception and motor competence

The third issue concerns the relationship between visual perception and impaired motor competence. As described in chapter two, Hulme and colleagues (Hulme et al., 1982; 1984). have investigated this in a number of studies by examining the correlation between performance on purely visual tasks and various motor measures and have proposed two rather different explanations of this relationship. Initially, they suggested that the relationship extended across the entire range of perceptual and motor performance. Put simply, the better one was at making perceptual judgements, the better would be one's performance on motor tasks (Hulme et al., 1982). Later, however, this view was modified to accommodate the findings of

their 1988 study which did not produce consistent results (Lord and Hulme, 1988). This led to a second formulation which stated that it was only when perceptual performance fell below a certain threshold that motor performance was affected.

Two approaches to refuting Hulme et al's propositions have been taken. On the basis of an analysis of the results of their studies and the logic of the arguments made, Henderson (1992) has drawn attention to a number of difficulties with the final position taken. For example, not only was the threshold notion introduced on a post hoc basis, but also the results of the first study in the series were incompatible with it. In the present study, when either the Clumsy or control group were considered on their own, the correlations between performance on the discrimination task and each of the five motor tasks showed no suggestion of any relationship. When the data from the two groups were combined, a significant positive correlation between visuo-spatial ability and the quality of performance both on TOMI and on figure drawing emerged. However, it was evident that this resulted from categorical differences between the groups rather than a continuous relationship. In addition, Powell and Bishop (1992) and Hoare (1991) find no evidence of meaningful correlations between the perceptual and motor measures at all. Thus, the results from this and from other studies do not confirm the view that poor perceptual processing of the type measured here represents an underlying causal deficit.

The role of vision in drawing
The fourth issue concerns the role of vision for Clumsy children in the performance of motor tasks. This was examined by manipulating the availability of visual feedback information in the copying task. As discussed in chapter two, Lord and Hulme adopted this methodology in an attempt to gather further support for their notion that visual perceptual problems are related to clumsiness. They predicted that in the visual feedback condition Clumsy children would be at a disadvantage because of their poor visual perceptual skills but that in the condition with no visual feedback this disadvantage would be reduced. This prediction ties in with

findings from the earlier study by Hulme et al. (1982) in which vision was manipulated at the input stage in a line-length matching task (see chapter two for details). They found that children performed more poorly in a cross-modal V-K condition compared to an intra-modal K-K condition and that Clumsy children performed more poorly than controls. No significant interactions were obtained in their study, but employing an identical task Hoare and Larkin (1991) report greater group differences in the V-K condition.

However, Lord and Hulme (1988) found that the removal of visual feedback information had an equally deleterious effect on both groups. They explain their results by saying that the fact that vision is still available at input in the V-K condition means that the Clumsy children are still at a disadvantage because of their poor visual perceptual skills. Their results are comparable with others that manipulate the availability of vision at the point of output (van der Meulen et al, 1991 a and b, see chapter two for further details). However, some individual data reported in these other studies suggests that there is a differential effect between some Clumsy and control children when vision is removed but that it is in the opposite direction to that predicted by Lord and Hulme (1988). That is, some Clumsy children are affected more by the removal of vision. This is precisely what was found in the replication study in relation to size copying. The results for absolute error showed a tendency for the Clumsy children to be worse in the V-K condition and this was seen in a clear interaction in the constant error results. These results tie in with other studies that have manipulated the availability of vision at input. They find that Clumsy children perform much more poorly than controls when vision is not available (von Hofsten and Rösblad, 1992; Jongmans, 1989). Several possible explanations for these results have been discussed in chapter two. The most appealing explanations are those relating to the way in which Clumsy children make use of visual and kinaesthetic perceptual information. They may be particularly sensitive to the removal of visual information because, contrary to what Lord and Hulme say, they usually depend heavily on visual information. They watch their hand

and the output carefully as they draw, perhaps frequently checking between the stimulus and their output. Performance would thus deteriorate if they were unable to use these strategies. This explanation is supported by findings from several studies. For example, van der Meulen et al. (1991) and Wann (1987) report that Clumsy children perform significantly more slowly than their peers when vision is available and that they visually monitor their movements more. Also Schoemaker (1992) noted that, when copying, Clumsy children looked at the stimulus figures more frequently than controls.

In addition, as Lord and Hulme point out, the children have to rely more on kinaesthesis in the V-K condition. If they are also poor at making sense of this information, this would help to account for their poor performance.

It is suggested that the method involving the manipulation of visual information is far more appropriate than the correlational approach in that it allows for the study of how children use different types of perceptual information within a movement context. However, there are several important points to note when employing this methodology. Firstly, the type of performance measures taken are of vital importance. It is evident from the present study and from previous studies that the effects of manipulating visual feedback information are only apparent in some performance measures. Ideally, therefore, a number of different performance measures should be taken until those that are particularly sensitive to the manipulation of visual feedback have been identified. Secondly, it was noted by Lord and Hulme that the fact that vision was still available at input in the V-K condition may have been a problem. In addition to their argument in relation to this, a more important point is that it produces a cross-modal condition which adds another confounding factor when making comparisons across performance in the different conditions. It is suggested that, to overcome this problem, it must be ensured that all conditions are intra-modal. This method of studying the role of vision in manual tasks is expanded in the following chapter.

Chapter Six

MANIPULATIVE SKILLS OF CLUMSY CHILDREN

6.1 Introduction

In the previous chapter a rather specific aspect of lack of coordination in Clumsy children was investigated. Although drawing is a common pastime for most children, this skill is not essential for daily living. In the present chapter the focus turns to the study of manipulative skills which are necessary for the performance of many everyday tasks.

It is commonly reported that Clumsy children experience difficulty with tasks that require fine manipulative skill such as fastening buttons, tying shoe laces and constructing models. Although most formal tests of motor competence involve tasks requiring such skill, there has been little detailed examination of the performance of Clumsy children on manipulative tasks. In this series of studies, therefore, it was decided to employ two tasks that require a small object to be manipulated in the hand and placed in a target position, both of which are familiar to Clumsy children. The first task involved inserting four cylindrical pegs into a peg board. Here, one hand plays an active role and is involved in the 'aiming' component of the task. Although the other hand is generally passive it may help in locating the hole or 'target'. In contrast to this, both hands are actively involved in the second task, buttoning fastening. Here, the fingers of one hand are primarily responsible for grasping the button and manoeuvring it through the hole or 'target'. At the same time, the fingers of the other hand locate the hole, widen it and pull the button through. To perform this task, the action of both hands must be coordinated in space and time.

This chapter is identical in organisation to chapter five. It comprises three studies, the first two of which describe performance on the two tasks in normal conditions. The third

study in this series examines the role of vision by removing visual information throughout performance of the tasks.

Since the investigations described in this chapter employ the same subjects and the same two tasks throughout, these are first described below.

6.2 General Method

Subjects: The children participating in the three studies which follow are described in chapter four. In the first study, 42 pairs of children, one Clumsy and one age-matched control were involved. In the second study, 16 of these Clumsy children were seen again 18 months later. In the third study the original 42 pairs of children were involved. Details of the selection of these children are provided in chapter four. The characteristics of individual children are provided in tables 4.5 and 4.6.

Procedure: Each child performed two manipulative tasks, administered individually either in their own schools or at home.

Peg Insertion Task. The child was seated at a table of an appropriate height (such that their forearms rested comfortably on the table and their feet were flat on the floor). On the table was a wooden board in the centre of which were four holes positioned in a line perpendicular to the child's body (see figure 6a). On either side of the holes was a recess into which pegs could be placed. Four cylindrical pegs were used (each 40 mm long and 10 mm in diameter). The child's task was to pick them up and insert them into the pegboard one at a time. The task was performed with the right and the left hand.

The children performed the task first with their preferred and then their non-preferred hand (preference was first established according to the hand used for writing). This fixed order was employed because pilot work showed that when

recess
for
pegs

recess
for
pegs
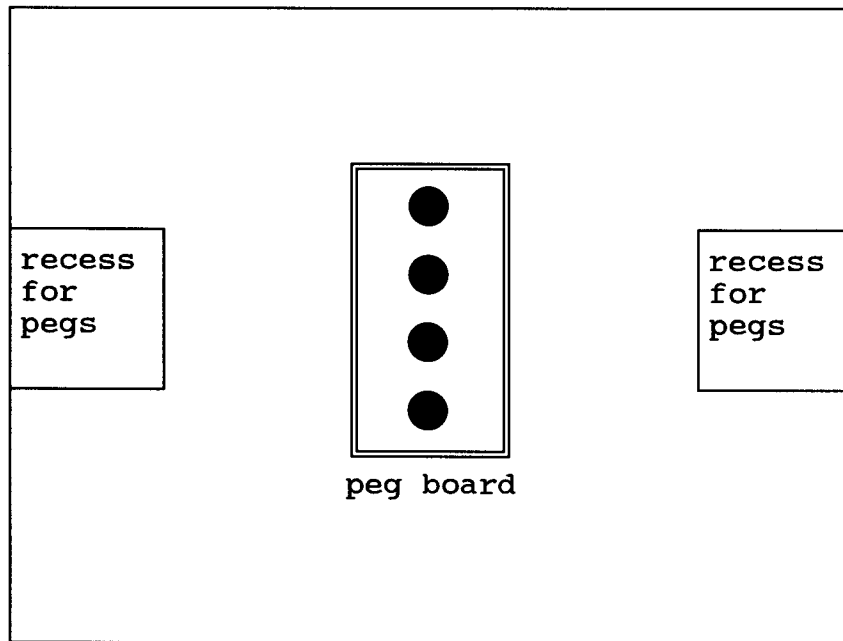
peg board

Figure 6a. Apparatus for peg insertion task showing position
of peg board and pegs.

supposed to be using the non-preferred hand many of the children transferred the peg to the preferred hand (despite clear instructions not to do so). For the same reason, only those trials with the preferred hand are used in the analyses.

Buttoning Task. The child was seated on a chair of an appropriate size and wore a waistcoat with three buttons (each 28mm in diameter) on the right hand side of it. The task was to fasten the buttons.

Following a demonstration, each of the tasks was performed under two conditions. In the first condition the children could see what they were doing (the Vision or V condition). In the second, they performed the task wearing a blindfold to exclude all visual information (the No Vision or NV condition). It was not possible to counterbalance the order of these conditions since pilot work showed that many of the Clumsy children and some of the younger controls were very apprehensive and even refused to attempt the task with a blindfold on before they had a go under normal conditions. Since video recordings were to be made of performance it was not possible to exclude visual information in any other way.

No instructions were given to the children regarding speed of performance.

A video recording was made of each child performing the two tasks. The video camera was positioned on a tripod approximately 2m. from the child to give a frontal view of the head, arms and hands.

Data Collection and Analyses

Before any analysis of performance was undertaken, the video tapes were first edited to minimise any possible biasing effects of scores from one task on another. Separate edited tapes for the buttoning and peg insertion tasks were made. On each tape the order of children on the videos was randomised across both age band (1-4) and group (Clumsy and control). The

V and NV conditions were also randomly arranged on the tapes. Once edited, the videos were scrutinised to produce two measures of performance:

Movement Outcome: This was quantified by measuring the time taken to complete each task (measured in seconds). This was calculated from the moment the child touched the first peg (or button) to the moment of finishing the insertion of the last peg (or button). In those instances where a child was unable to complete a task, he was assigned the time taken by the slowest child of the same age.

Movement Quality: A qualitative analysis was undertaken by completing an observation checklist for each task that the children performed. For the peg insertion task a checklist was only completed for performance with the preferred hand.

Details of the development and content of these checklists are given in Appendix 3. A summary of the checklist for peg insertion and buttoning is provided in table 6.1. An item was noted down once if it was observed once or more during performance of the task. Inter-rater reliability was found to be high for both tasks (96% for peg insertion and 90% for buttoning).

The checklists for the peg insertion task were completed by a researcher in motor development, those for the buttoning task by an Occupational Therapist. Both observers were experienced in observing children with movement difficulties and both were blind as to the original classification of the children as Clumsy or control.

Table 6.1. Summary of contents of observation checklists for peg insertion and buttoning tasks

Peg insertion	
1. Body Control:	Poor posture
	Poor grip
	Fingers stiff
	Change of grip
	Lack smoothness
	Odd
	Hesitation
2. Motor overflow:	Exaggerated movement
	Tapping
	Additional movement
	Associated movement
3. Spatial errors:	Difficulty locating peg
	Difficulty locating hole
	Seeking movements
	Over reach
	Under reach
	Misalignment
	Misplacement
4. Force errors:	Excessive force
5. Other errors:	Distraction
	Poor exploration
	Transmission
	Peg dropped

Buttoning	
1. Body Control:	Poor posture
	Poor grip
	Fingers stiff
	Change of grip
	Difficulty pulling
	Difficulty pushing
	Lack smoothness
	Odd
	Hesitation
2. Motor overflow:	Exaggerated movement
	Tapping
	Additional movement
3. Spatial errors:	Difficulty locating button
	Difficulty locating hole
	Seeking movements
4. Force errors:	Excessive force
5. Other errors:	Distraction
	Poor exploration
	Unable to fasten button

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6.3 The speed and quality of movement on two manipulative tasks

6.3.1 Introduction

The specific aim of this study was to provide a comprehensive description of how Clumsy children differ from normal in the performance of everyday manipulative tasks.

From the review of literature relevant to the description of how such tasks are performed, various observations of childrens' difficulties emerge. One of the most commonly reported is slowness of performance. This is the most easily and reliably measured aspect of performance and thus forms the starting point for this investigation. By measuring overall speed in the two tasks, it was possible to examine the relationship between them.

A few studies have attempted to document the quality of movement of Clumsy children when performing manual tasks. However, as discussed in chapter two, most of these have employed complex kinematic analyses and restrained aiming tasks. One exception is the study by Kalverboer and Brouwer (1983). They described the performance of Clumsy children on a manipulative task using observation checklists, a technique that requires a minimum of equipment and technological expertise.

The present series of studies adopts a methodology similar to that used by Kalverboer and Brouwer but attempts to expand on their findings by using a slightly different type of checklist based on another model of performance which is described in Appendix 3.

Starting with an overall measure of movement quality and movement time the performance of the Clumsy children was

compared to controls of the same age and IQ. The relationship between speed and quality was also examined. Analysis of the performance of Clumsy children was then extended to provide information on different aspects of performance such as motor control (eg grip, fluency of movement), spatial characteristics (eg accuracy in location and alignment of materials) and force characteristics. Finally, performance on some of the individual items from the checklists was examined.

As was the case for drawing skills, this cross sectional data produced age effects which were interesting but difficult to interpret. Thus, a second study was designed to examine the manipulative skills of a sub-set of the Clumsy children on a second occasion.

Method
In this and the following study only performance under normal conditions (ie. the V condition) is described.

6.3.2 Results
Since there were no significant differences between the performance of girls and boys in the speed or quality of performance (F<2 in all cases), gender was not included as a factor in any of the following analyses.

An overall view of performance
In order to obtain an overall view of performance of the two groups of children, an examination was first made of differences in speed and quality of performance.

a. Speed of Performance
The results for completion time of the two tasks (in seconds) are shown in figure 6b for the two groups of children across the four age groups. Group (Clumsy and control) by Age (groups 1-4) ANOVAs were conducted using the time taken to complete each task as the dependent variable. These analyses indicated that the Clumsy children performed significantly more slowly than the controls in both the peg insertion and the buttoning

Peg Insertion

Time to complete (secs)

Age Band

—*— Clumsy   —□— Control

Buttoning

Time to complete (secs)

Age Band
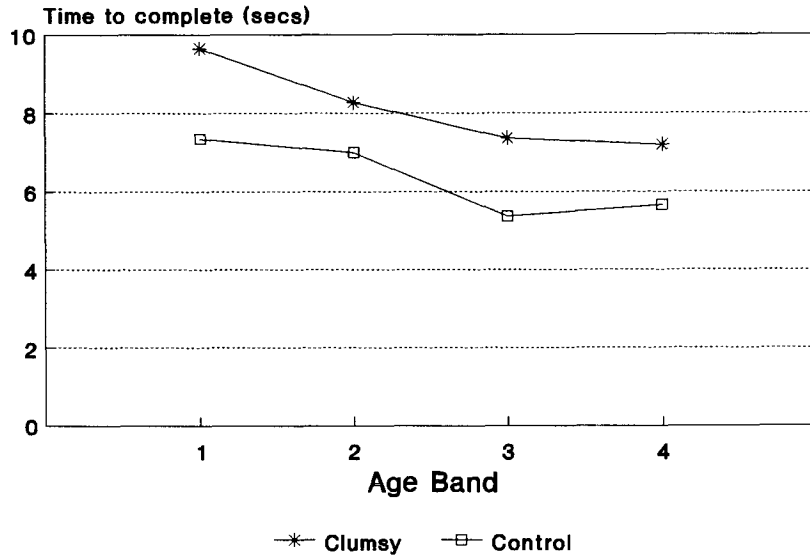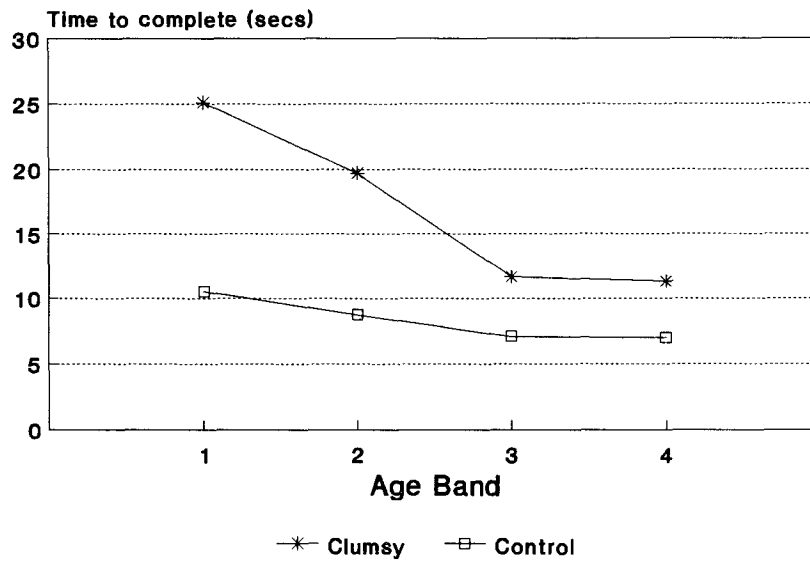
—*— Clumsy   —□— Control

Figure 6b. Time taken for Clumsy and control children to complete peg insertion and buttoning tasks

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task (F=27.52 df=1,76 p<.0001 and F=24.56 df=1,76 p<.0001 respectively). Both analyses also yielded a main effect of age with the younger children performing significantly more slowly than the older ones (F=9.03, df=3,76 p<.0001 for peg insertion and F=5.63 df=3,76 p<.005 for buttoning).

In neither task was the Group by Age interaction significant (F<3 in both cases). From figure 6b, however, it can be seen that the difference between the Clumsy and control children is greatest for the youngest children. This is particularly true for the buttoning task. Despite the fact that it is not strictly legitimate from a statistical viewpoint, post hoc analyses using Tukey's procedure reveal that the difference between the groups is significant for age band one only in the peg insertion task and for age bands one and two in the buttoning task.

b. Quality of performance

Due to some data loss, information on the quality of performance was only available for 36 of the children from each group. This left a total of 9 children in each group in each of the four age bands.

Starting with a broad measure of quality of performance, the total number of errors observed for each child was first examined (see figure 6c). When subjected to analysis of variance, this data showed a similar pattern to completion time. The Clumsy children displayed a significantly greater number of errors than the controls in both the peg insertion and the buttoning tasks (F=52.45, df=1,64 p<.0001 and F=47.51, df=1,64 p<.0001 respectively). Also, younger children made significantly more errors than older children on both tasks (F=8.68, df=3,64 p<.0001 and F=4.93, df=3,64 p<.005 respectively). In neither task was the Group by Age interaction significant.

Peg Insertion

Mean number of errors

Age Band

—✳— Clumsy   —▢— Control

Buttoning

Mean number of errors

Age Band
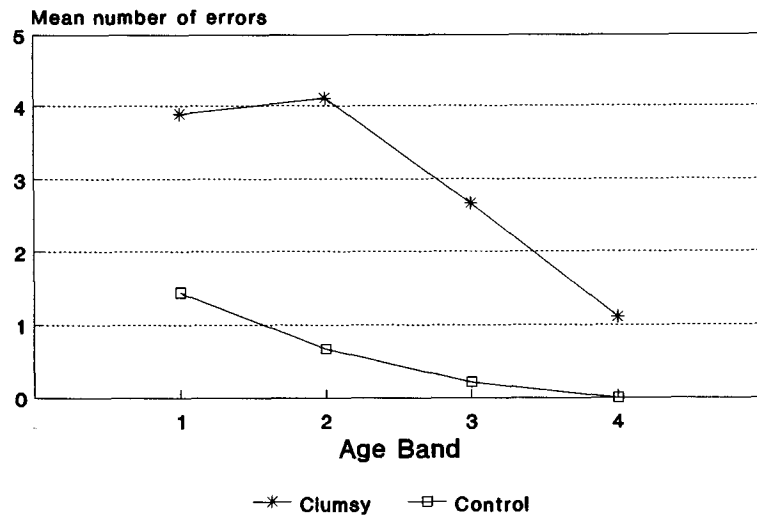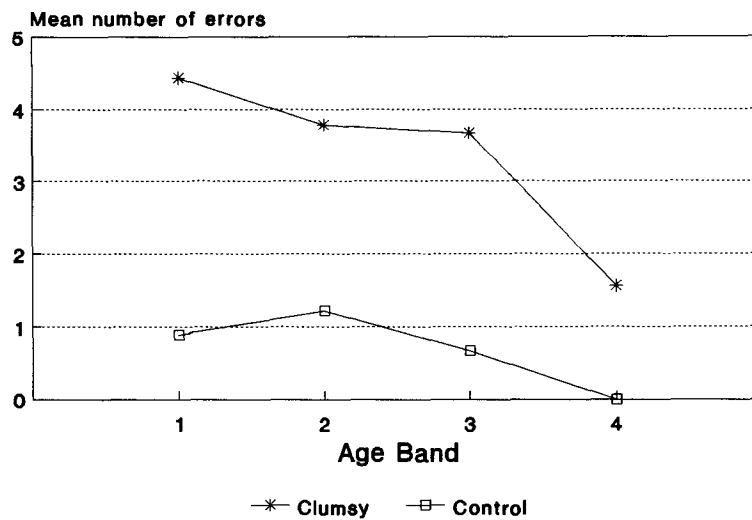
—✳— Clumsy   —▢— Control

Figure 6c. Mean number of errors for Clumsy and control children in peg insertion and buttoning tasks

The relationship between performance on the two tasks
a. Speed
The speed of performance on both tasks is shown in figure 6d for individual subjects. The correlation across all 84 children between time taken to complete the two tasks was significant (r=.47, p<.001) giving a broad indication that childrens' performance on the two tasks is related to some extent. However, when considering the groups separately, the correlation was only significant for the controls (r=.54, p<.001) and not for the Clumsy children (r=.36). As seen from the figure, these results may be explained by enormous individual differences in the pattern of performance within the Clumsy group which are not evident in the control group.

b. Quality
The number of errors exhibited in both tasks is shown in figure 6e for individual subjects. The correlation between the total number of errors observed in each task reveals a significant relationship when both groups are taken together (r=.56). Considering the groups separately, however, this relationship was not significant (r=.33 for the Clumsy group, r=.22 for controls). The pattern of scores in the figure suggests that this result is obtained from differences between the groups on both measures, rather than a continuous relationship throughout the entire data set.

The relationship between errors and speed in each task
Another question of interest concerns the nature of the relationship between speed and total number of errors. This is shown for individual subjects on each task in figure 6f. In the peg insertion task, when taking both groups together, it was found that speed of performance correlated significantly with the number of errors observed (r=.46). That is, faster completion times are associated with fewer errors. However, when the groups are considered separately, the correlations are only significant for the controls (r=.39, p<.01) and not for the Clumsy group (r=.21). These correlations are not significantly different from each other.
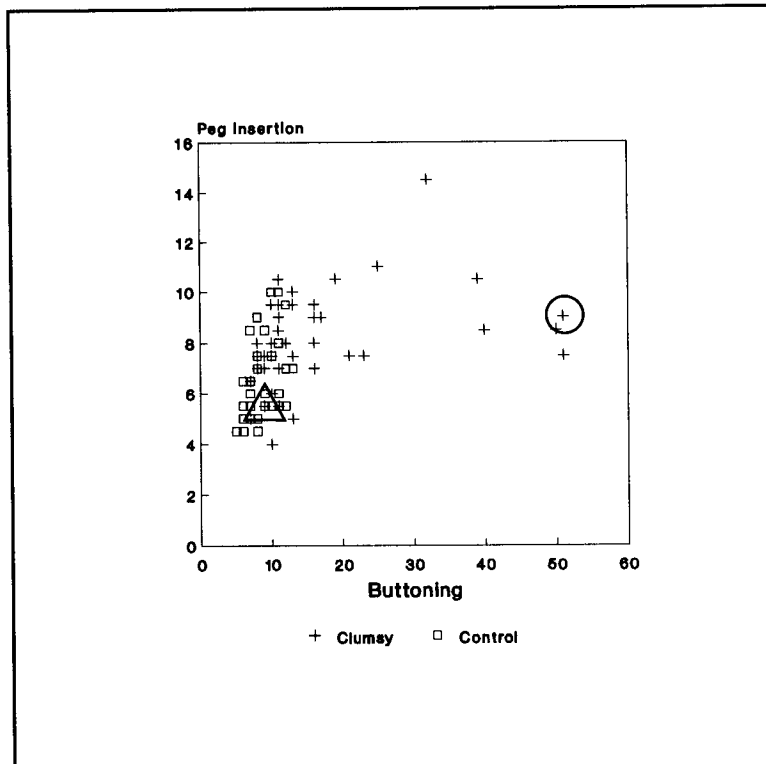
Figure 6d. Speed of performance (seconds) of individual subjects in peg insertion and buttoning tasks.
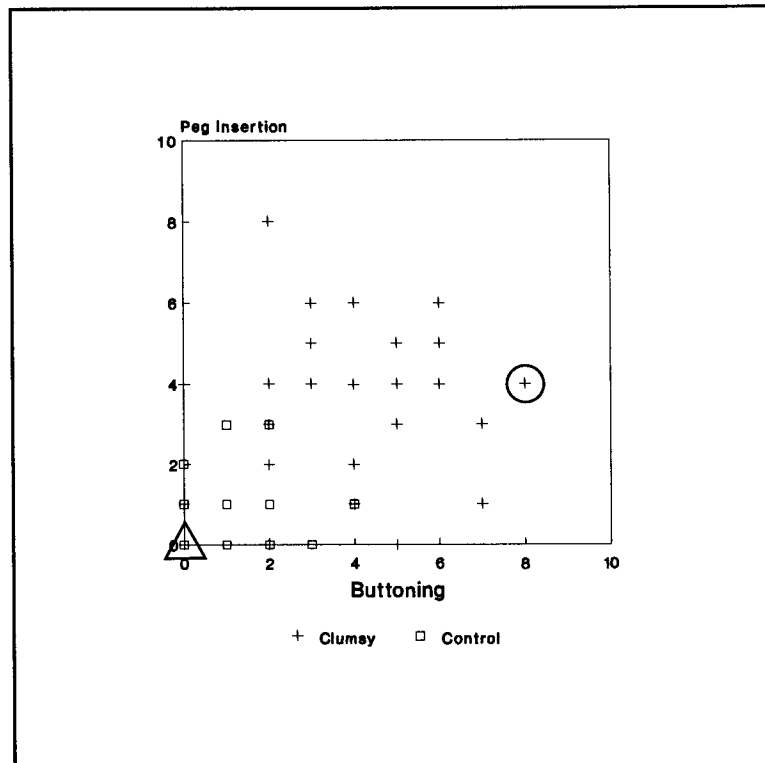
Figure 6e. Quality of performance (total no. errors) of individual subjects in peg insertion and buttoning tasks.

Markers represent performance of a 'good' (triangle) and 'poor' (circle) Clumsy child mentioned in the text.

Peg Insertion

No. errors

+ Clumsy   □ Control

Time to complete

Buttoning

No. errors

+ Clumsy   □ Control

Time to complete

Figure 6f. Speed and quality of performance of individual subjects in peg insertion and buttoning tasks.

Similarly, in the buttoning task, the correlation is significant when considering all of the children together (r=.66). In this case when the groups are separated, only the correlation for the Clumsy group is significant (r=.57, p<.001), that for the controls is not (r=.24). These two correlations are significantly different from each other. As can be seen in the figure, this difference is partly explained by the fact that, whereas the range of scores is very small in the control group, it is large in the Clumsy group.

Individual differences in performance

In previous chapters considerable individual variation has been noted within the two groups of children in terms of overall motor competence and in drawing skill. From the figures just presented it can be seen that there are also individual differences in both aspects of performance on these manipulation tasks.

As with the figure drawing scores in chapter five, these individual differences were investigated by classifying the children according to whether they performed the tasks well (ie. fast or with few errors) or poorly (ie. slow or with many errors). As in chapter five, the distinction between 'good' and 'poor' performance was established according to whether or not performance fell within one standard deviation of the control group mean.

In terms of completion time, although most of the Clumsy children performed slowly in the two tasks, there were some who performed as fast as controls (11 in peg insertion and 9 in buttoning). Similarly, while most of the control children performed quickly, a few of them were classified as 'slow' (10 in peg insertion and 13 in buttoning).

In terms of movement quality, although most Clumsy children exhibited a large number of errors, a few performed as well as the control children (12 in peg insertion and 7 in buttoning). Once again, there were also a few control children who

performed rather poorly (4 in peg insertion and 6 in buttoning).

Considering both aspects of performance together, most Clumsy children performed more slowly <u>and</u> with more errors than controls. This pattern of performance in one Clumsy child is indicated by a circle in figures 6d, e and f. He was one of the youngest in the Clumsy group and his performance was considerably worse than that of the controls both in terms of speed and quality of movement. This is particularly true for the buttoning task, in which he displayed 8 errors and was unable to fasten the button so was assigned the slowest time for his age group. In contrast to this child, a small number of Clumsy children performed quickly and with few errors (5 in peg insertion and 4 in buttoning). This pattern of performance, however, is consistent across the two tasks for only one child. His scores are indicated by a triangle in figures 6d, e and f. He was one of the oldest in the sample at 12 years, 3 months and had a score of 5 on the manual dexterity tasks on the TOMI (and a total score of 7.5). This suggests that he does experience considerable difficulties with other motor tasks.

To this point the focus has been on only the total number of errors for each child on the observation checklists. Although this provides a useful composite measure of movement quality, more detailed aspects of performance were also investigated by focusing on the different sections of the checklists. Since the number of errors displayed by children in the control group was so small, the remainder of the results section focuses on the quality of performance of the Clumsy children only.

Characteristics of the Clumsy children

a. Different components of performance

As described in Appendix 3, the organisation of the items in the observation checklists is based on a model that considers a number of different components of performance. In order to describe the characteristics of the Clumsy children in more detail, these groups of items are considered separately below. At the same time, differences in performance across the tasks are examined. Since the structure of the checklists used for the peg insertion and buttoning tasks were identical, performance on the two tasks may be compared directly. The number of Clumsy children exhibiting each item is shown in table 6.2 for both tasks. Due to some task differences, the item content of the two checklists is slightly different (those items only applicable to one of the tasks are indicated by bracketed items and figures in the table).

Motor control:

The items included in this category relate to several different aspects of motor control. Firstly, there are items concerning general control of the body in terms of how the child sits and holds the object to be manipulated. Also included here are difficulties with pushing and pulling the button through the button hole, which seem to occur as a consequence of having a poor grip on the button. Then there are items that describe the general movements of the arm and hands (eg lack of smoothness, hesitation).

It can be seen in table 6.2 that poor posture was noted for children in both tasks, but for more in the buttoning than the peg insertion task. Poor grip was frequently observed in both tasks. In fact, it was by far the most common observation in the buttoning task, being displayed by more than half of the children (21/36). In the peg insertion task it was the third most common error (13/36). 'Poor grip' was recorded if the grasp on the peg or button appeared immature, weak or in any way 'odd' and thus covered a range of grip configurations. In

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Table 6.2. Number of Clumsy children exhibiting each item in the Vision (V) condition. (Bracketed observations and figures apply to only one of the tasks). n=36.

Errors	Peg Insertion	Buttoning
Motor Control:		
Poor posture	5	11
Poor grip	13	21
Fingers stiff	4	7
Change of grip	7	2
(Difficulty pushing)	–	(19)
(Difficulty pulling)	–	(15)
Movements lack smoothness	5	15
Movements look odd	8	7
Hesitation	4	1
Motor Overflow:		
Exaggerated movements	7	5
Tapping	4	4
Additional movements	1	0
(Associated movements)	(2)	–
Spatial Errors:		
Difficulty locating peg/ button	0	4
Difficulty locating hole	0	8
Seeking movements	1	1
(Over reach)	(0)	–
(Under reach)	(0)	–
(Misalignment)	(23)	–
(Misplacement)	(0)	–
Force Errors:		
Excess Force	14	0
Other Errors:		
Distraction	0	2
Poor exploration	0	9
(Transmission)	(1)	
(Peg dropped)	(7)	–
(Unable to fasten button)	–	(2)
TOTAL	73	97

– item not applicable to task

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some cases, particularly in younger Clumsy children, the peg or button was held in the palm of the hand rather than just the finger tips. This meant that it could not be manipulated very well. In the buttoning task approximately half of the children had difficulty pushing and pulling the button through the button hole.

In both tasks, some children were noted to have movements that lacked smoothness and fluency (this was more common in the buttoning task) and for some, their movements looked odd or hesitant.

Motor Overflow:

The items in this category describe movements that have no obvious function in the task and thus represent an 'overflow' of movement. As can be seen in table 6.2, in both tasks children showed exaggerated movements when releasing the peg and tapped the peg or button. Two children showed associated movements of the supporting hand.

Spatial characteristics:

Items in this category relate to inaccuracies in aiming as well as more general problems in the way the child finds his way around. In the peg insertion task more than half of the Clumsy children (23/36) misaligned the peg with respect to the hole. That is, although they reached the target position, they were unable to insert the peg cleanly. This was the most common error for this task. In the buttoning task they had difficulty locating the button and button hole, errors which represent more global problems in terms of finding their way around the workspace and locating targets.

Force characteristics:

The one item in this category concerns the use of an inappropriate amount of force. For example, using excess force when inserting the peg into the hole. This was the second most common error in peg insertion but was not noted for any child in the buttoning task.

Other observations:

Observations from the last category show that seven children dropped a peg onto the table, presumably the result of having a poor grip on the peg. There were nine children for whom 'poor exploration' was recorded in the buttoning task. This error was recorded when children had difficulty locating the button and/or button hole and used unusual or unsystematic search strategies. For example, one child felt along the bottom hem of the waistcoat in search of a button hole. Two children were completely unable to fasten the buttons and the same two were also distracted from the task. Perhaps their attention was more easily broken because they found the task more difficult than the other children.

b. The pattern of errors across the age groups

It has already been mentioned that few studies with Clumsy children have investigated age effects and that this was a major aim of the present investigation. The main analysis above showed that the younger Clumsy children displayed a greater number of errors overall when compared to older children. In order to investigate these age effects in more detail, those errors that were most commonly displayed by the Clumsy children were identified. For these items, the pattern of performance across the four age groups was then examined. This is shown in table 6.3 for both tasks. Direct comparisons can be made between the four age groups since each consist of 9 Clumsy children.

Motor control:

Turning first to the errors of motor control, there is some indication that in both tasks posture improves with age, although not until the children reach about the age of eleven. In terms of problems with grip, a clearer and more steady improvement can be seen across the age groups. However, other aspects of motor control such as lack of smoothness and movements that look odd do not show such clear improvements with age. In fact in the buttoning task there appears to be some increase in these errors with age. In terms of

Table 6.3. Number of Clumsy children in each age group (n=9) displaying individual errors in the Vision (V) condition.

PEG INSERTION	AGE GROUP				
Errors:	1	2	3	4	TOTAL
Motor control: Poor posture	2	2	1	0	5
Poor grip	7	4	2	0	13
Lack smoothness	1	2	2	0	5
Look odd	3	1	3	1	8
Spatial: Misalignment	9	8	4	2	23
Force: Excess Force	4	5	4	1	14
Other: Peg Dropped	5	2	0	1	7
BUTTONING					
Motor control: Poor posture	3	4	3	1	11
Poor grip	8	7	5	1	21
Pushing	6	6	6	1	19
Pulling	4	5	5	1	15
Lack smoothness	2	4	5	4	15
Look odd	1	2	2	2	7
Spatial: Locate hole	3	1	2	2	8
Other: Cannot fasten	2	0	0	0	2
Poor exploration	2	3	2	2	9

Age Groups: 1   5-6 years
            2   7-8 years
            3   9-10 years
            4   11+ years

difficulties in pulling and pushing the button, while there appears to be no improvement with age across the first three age groups, only one of the eldest children experiences any difficulty in this area.

Spatial characteristics:

In relation to spatial errors, with increasing age there is a reduction in the number of children misaligning the peg, although there is little improvement in the first two age groups. In contrast, problems with location in the buttoning task do not seem to diminish with age.

Force characteristics:

Errors of force control were only evident in the peg insertion task. From the table it can be seen that the only indication of improvement in this error is in the oldest children.

Finally, the problem of dropping pegs appears to diminish with age and it is only children in the youngest age group who are unable to fasten a button.

Task differences

Although there is remarkable similarity in the overall results from the two tasks, there are also some important differences to be noted. Firstly, from figure 6b it can be seen that the difference between the two groups of children is greatest in the buttoning task.

Secondly, in terms of the quality of performance, when one looks at those items that are common to both tasks, it can be seen that more children display errors in the buttoning task than in peg insertion. In particular, more children are noted to have poor posture, poor grip and movements that lack fluency. More of them also show poor exploration and have problems locating the object and target.

Thirdly, the changes in performance with age seem to be task dependent. For example, posture and grip improve more steadily

in the peg insertion task than in buttoning.

These differences in the results from the two tasks reflect differences in the task demands. Firstly, in the buttoning task the child's workspace is on his body rather than on a table in front of him. This helps to explain why children had more problems of posture and location in the buttoning task. Secondly, there are differences in both the amount and the type of manipulation that is involved in the two tasks. In the peg insertion task, manipulation of the peg occurs when it is first picked up and then when it is turned to orient it to the hole just prior to insertion. In contrast, in the buttoning task the button is manipulated throughout the task. In this case, the action required involves the complex manipulation of the button in and between the hands as it is manoeuvred through the button hole. This helps to explain why more children displayed problems with grip in this task.

6.3.3 Discussion

The examination of performance on the two object manipulation tasks began with a measurement of speed and the general results indicated that Clumsy children perform more slowly than their age peers. This finding is consistent with some previous studies involving handwriting (Fisher, 1990; Søvik et al. 1987) and more restricted manual tasks, such as pointing to a target (Geuze & Kalverboer, 1987; van Dellen & Geuze, 1988). Some other studies, however, fail to find differences in the speed of performance between Clumsy and control children (eg Rubin and Henderson, 1982) and one study reports differences in the opposite direction, with Clumsy children performing more quickly than controls (Lord, 1987).

These inconsistent findings regarding the speed of performance may partly be explained by individual differences within the Clumsy groups. As mentioned in chapter two in relation to handwriting speed, while some Clumsy children perform particularly slowly, there are others who are fast but careless. The main group results, therefore, will depend upon

the relative numbers of Clumsy children in the study exhibiting these quite different styles of performance.

The individual results of children in the present study showed that, while most of the Clumsy children preformed slowly compared to controls, there were a few who completed the tasks quickly. However, no suggestion was found of a trade-off between speed and the quality of performance that has been reported in other studies (eg Lord, 1987; O'Hare and Brown, 1989).

The speed of performance of Clumsy children will also depend on the instructions given. While in the present study, no instructions were given regarding speed, in others it is not clear whether or not the children were instructed to perform quickly.

The results suggested that the group differences in speed of performance could be qualified by both the nature of the task and the age of the children. Although this was not confirmed by the statistical analyses, it seemed that the difference between the two groups of children was greater for the younger children in both tasks.

In many case studies, clumsiness is a word used as an adjective to describe an action as well as a group of children who have movement difficulties. Although, at a certain level, we all know what this means, there is a need to go beyond this level of description of movement quality. In the present study, an attempt was made to achieve this by using observation checklists to systematically record and describe a variety of difficulties experienced by Clumsy children.

A major part of the investigation was the development of such checklists for the peg insertion and buttoning tasks (described in Appendix 3). These were found to be reliable and useful tools for examining the quality of movement in Clumsy children.

In terms of overall movement quality, although there were some individual differences, the Clumsy children were generally worse than the controls. They performed with up to 8 errors, whereas the performance of most of the control children was completely error free.

When the results were examined in relation to the different components of performance, it was found that the Clumsy children had problems in all areas. In terms of motor control, many of them had poor posture and grip and their movements lacked smoothness and fluency. They also had difficulty with the spatial and force characteristics of movement, aiming inaccurately and using inappropriate levels of force. In addition, they exhibited more global problems such as poor attention and the use of inappropriate performance strategies.

The age range of children included in the study allowed for the investigation of characteristics of performance at different ages and it was found that the individual items in the checklists were particularly useful in this respect. As in the previous series of studies on drawing skills, two findings emerged which warrant further investigation. Firstly, improvements with age were found both in terms of overall performance and in some individual errors. Secondly, there was some suggestion that certain aspects of motor control are resistant to change.

However, since this was only cross sectional data, it was not possible to determine whether these were real age differences or whether they just happened to occur in this particular sample of children. The only way to distinguish between these two possible explanations was to undertake a longitudinal analysis.

In the study that follows, an attempt was made to investigate these issues by re-examining the manipulative skill of 16 of the Clumsy children after a period of 18 months.

6.4 What does happen as children get older? A Longitudinal Analysis

6.4.1 Method
Subjects: For various reasons it was not possible to follow up all of the Clumsy children who participated in the first study. Some had moved out of the area and others did not wish to participate. However, an acceptable number of sixteen children were available. Their details are given in table 4.6 in chapter four and they are the same sixteen who participated in the follow up study described in chapter five. They ranged in age from 7.8 years to 9 years, they had verbal IQ's of between 80 and 123 and TOMI scores of between 4.5 and 16.

For this phase of the work a decision was made to follow up only Clumsy children since the controls were performing so well that no improvements would show up due to the simple nature of the tasks and the content of the observation checklists, which were designed to describe children having difficulties. However, as a comparison for overall speed of performance, older controls were selected from the original study to match the Clumsy children on age, sex and as closely as possible on verbal IQ. No comparison was made with the controls for movement quality since there was little variance in the control group with nearly all of them being error free.

Procedure
The Clumsy children were seen 18 months after the first study. They were seen individually using the same procedure as previously.

6.4.2 Results
a. Speed of Performance
The first question of interest in the present study was whether the Clumsy children improved their performance over the 18 month period. Table 6.4 shows the mean completion times for the Clumsy children in the original and follow up studies. T-tests conducted on the time taken to complete each task,

indicated that the Clumsy children performed no faster at follow up compared to their performance in the original study (t=0.19, df=15, p<.86) on the peg insertion task. However, in the buttoning task the Clumsy children improved their performance by about 10 seconds, a statistically significant amount (t=3.35, df=15, p<.005). Whereas previously some of the children could not complete the task and were awarded the slowest time from their age band, all could complete the task at follow up. Thus, only the results from the buttoning task confirm the age effects that were found in the first study.

Table 6.4. Mean time (seconds) for Clumsy children to complete tasks in original and follow up study

	ORIGINAL	FOLLOW UP
Peg Insertion	8.44	8.31 ns
Buttoning	23.94	12.81 **

** p<.005

Having found some improvement in performance over time, the question of whether the Clumsy children still differed from their age peers was then addressed. Table 6.5 shows the mean completion times for the Clumsy children and age-matched controls from the previous study. Eighteen months later the Clumsy children still performed significantly more slowly than their well coordinated peers on both the peg insertion and buttoning task (t=4.48, df=30, p<.0001 and t=3.35, df=30, p<.005 respectively).

Table 6.5. Mean time (seconds) for Clumsy and control children to complete tasks

	CLUMSY	CONTROL
Peg Insertion	8.31	5.38 ***
Buttoning	12.81	7.94 **

*** p<.0001
** p<.005

b. Quality of performance

Table 6.6 shows the difference between the mean number of observations for Clumsy children in the original and the follow up study. On this measure, T-tests conducted on the total number of observations for each task indicated that the Clumsy children had improved their performance on both the peg insertion and the buttoning task (t=3.28, df=15, p<.005 and t=3.03, df=15, p<.01 respectively). This confirmed the finding in the original study that there was an overall improvement in the total number of errors with increasing age.

Table 6.6. Mean number of errors for Clumsy children in original and follow up study

	ORIGINAL	FOLLOW UP
Peg Insertion	3.94	2.25 **
Buttoning	4.19	2.06 *

** p<.005
* p<.01

Task differences

So far, the results of this study suggest that the developmental pattern of the two tasks is rather different. The childrens' performance improved more in buttoning than in peg insertion. In the buttoning task, a significant reduction in completion time was accompanied by a corresponding reduction in the number of errors displayed. In contrast, although the children displayed fewer errors in peg insertion at follow up, there was no significant reduction in completion time.

Patterns of change in individual errors

The results from the first study suggested that while some errors diminish with age, others do not. Individual errors displayed at first and second testing are shown in table 6.7 for the sixteen Clumsy children involved in this study. Turning first to errors of motor control, it can be seen that in both peg insertion and buttoning, improvements were made in

Table 6.7. Number of Clumsy children exhibiting each item in the original (O) and follow up (F) study. (Bracketed observations and figures apply to only one of the tasks). n=16.

Errors	Peg Insertion		Buttoning	
	O	F	O	F
Motor Control:				
Poor posture	3	1	7	1
Poor grip	10	2	13	8
Fingers stiff	3	3	5	3
Change of grip	4	1	2	0
(Difficulty pushing)	-	-	(8)	(8)
(Difficulty pulling)	-	-	(8)	(6)
Movements lack smoothness	5	5	9	7
Movements look odd	4	3	5	6
Hesitation	0	0	0	0
Motor Overflow:				
Exaggerated movements	2	2	0	0
Tapping	3	1	1	0
Additional movements	0	0	0	0
(Associated movements)	(2)	(0)	-	-
Spatial Errors:				
Difficulty locating peg/ button	0	1	3	1
Difficulty locating hole	0	1	2	1
Seeking movements	0	0	0	0
(Over reach)	(0)	(1)	-	-
(Under reach)	(0)	(0)	-	-
(Misalignment)	(12)	(9)	-	-
(Misplacement)	(0)	(0)	-	-
Force Errors:				
Excess Force	8	5	0	1
Other Errors:				
Distraction	0	0	1	0
Poor exploration	0	0	4	0
(Transmission)	(1)	(0)	-	-
(Peg dropped)	(4)	(0)	-	-
(Unable to fasten button)	-	-	(2)	(0)
TOTAL	42	25	52	28

- item not applicable to task

terms of posture. At follow up only one child showed a poor posture in both tasks. It can also be seen that fewer children showed a poor grip at follow up. In this case, more children improved in peg insertion than in buttoning. At follow up half of the children still showed a poor grip when buttoning. About the same number of children also continued to have difficulties in pushing and pulling the button through the material.

When one looks at those items relating to the nature of the movements themselves, it can be seen that there was little improvement over time. At follow up, several children still had movements that lack smoothness and look odd.

In terms of problems with 'motor overflow', so few of these children displayed errors of this kind in the first study that there was little room for change. However, it can be seen that there were slight reductions in the number of children who tapped the peg and button.

The next section of the checklists concerns spatial errors. Once again, most of these were only exhibited by a few children in the first study and there was little change in the follow up. However, it can be seen that in the peg insertion task, where previously none of these children displayed errors such as locating the peg and over reaching, they were noted in one or two children at follow up.

Two errors that were more common to these children in the first study were misalignment and excess force in the peg insertion task. In both cases the number of children displaying these errors decreased by only three.

There was also a decrease in the number of children who showed poor exploration in the buttoning task and the one child who had originally been observed to be easily distracted from the task was now better able to concentrate. Finally, no child dropped a peg or was unable to fasten buttons at follow up.

6.4.3 General Discussion

In this investigation detailed observations have been made of performance on two manipulative tasks in conjunction with measuring overall speed. The findings show that Clumsy children are generally slower and exhibit a wide range of errors relating to motor control and the temporal, spatial and force characteristics of movement.

In the cross sectional analysis, when individual errors were examined, it was found that some improved with age whereas others did not, echoing the results from chapter five. These differences in age were investigated further by following some of the Clumsy children over an 18 month period and the previous results were generally confirmed.

What follows focuses on a discussion of the possible influences of poor performance of the Clumsy children. Firstly, why do they perform more slowly than their age matched controls?

Slow movement times have been reported in several other studies of Clumsy children (Schellekens et al., 1983; van Dellen, 1987). In these, more restricted movements, such as pointing to a target, have been employed along with sophisticated movement analysis techniques. The findings from these studies have led to explanations of slowness in terms of an inaccurate distance covering phase that is of a short duration. The consequence of this is that more time is spent on the feedback controlled phase of the movement in order to reach the goal. This explanation may be relevant to the peg insertion task since it shares a similar 'aiming' component. However, it is difficult to see how this could explain slow performance in the buttoning task. In this case it is more useful to turn to the findings concerning the quality of movement.

With the use of the checklists a number of different aspects of movement quality in Clumsy children have been described. It is now possible to speculate on what might be the origin of

the different movement errors observed.

Motor control:

The checklists contained a number of errors that were categorised as problems of motor control. The first of these was poor posture, which was noted in several Clumsy children. It has already been suggested that some children displayed postural errors because they had to bend over to perform the buttoning task. In addition, there is evidence to suggest that postural control problems in Clumsy children occur at the neuromuscular level (Williams & Woollacott, 1988). However, the results did suggest that these problems diminished with age.

One of the most common errors exhibited by Clumsy children in both tasks was a poor grip. This error was recorded if any one of a variety of characteristics was observed (for example if the grip looked weak, immature or in any way awkward or odd) and thus included a variety of grip configurations. Although there are several other studies of Clumsy children that employ manual tasks, the type of grips employed and their significance has not been investigated.

Intuition says that poor grip itself may cause some of the other errors observed such as dropping the peg, being unable to fasten a button, and having difficulty pulling and pushing the button through the button hole. It would be interesting to know whether different grip configurations of Clumsy children do have any clinical significance. In order to investigate this it would be useful to have a developmental framework for grips used in manipulative tasks. This would require a classification firstly of grip configurations and secondly, of manipulations which depend on the organisation and coordination of movements of the digits.

In relation to the first of these, several studies have been carried out to examine normal development of the use of pens and pencils (Rosenbloom and Horton, 1971; Saida and Miyashita,

1979), a paintbrush (Connolly and Elliott, 1972) and a spoon (Gesell and Ilg, 1937; Connolly and Dalgleish, 1989).

In relation to the classification of manipulative action, the system devised by Elliott and Connolly (1984) describes the common intrinsic manipulative patterns employed in different manual tasks such as squeezing a syringe and unscrewing the lid of a jar. This system, however, is based on normal adult performance and is thus of limited value for clinical or developmental work. Separate assessment procedures do exist for such conditions as cerebral palsy (Holt, 1965) and rheumatoid arthritis (Dickson and Nicolle, 1972). However, these have used whatever descriptions of action were convenient for the particular condition and consequently there is a lack of comparability between methods (Elliott, 1979).

Since there has been little systematic description of patterns of grasp and digit coordination in the area of manipulative skill, there is no framework to describe what has been observed as 'poor grip' in this study in any more detail. However, a broad distinction may be drawn between two rather different observations of 'poor grip' in the study. Firstly, it was observed that some children adopted a palmar grip and therefore failed to successfully manipulate the peg or button with the fingers. Secondly, a weak or awkward grasp on the peg or button was observed in some children. Speculating on the relative significance of each of these observations, it is suggested that the former reflects immaturity or 'delay' since the general developmental pattern is from palmar to tripod grip. In contrast, the latter observation suggests that performance is different from normal rather than simply delayed. However, since some children exhibited both types of poor grip (eg a weak or awkward palmar grip) it was not possible to investigate this distinction more formally. Furthermore, the finding that problems with grip do diminish with age suggests that this error is more a result of 'delayed' rather than 'deviant' performance. Alongside this improvement in grip improvements were found in other errors,

with fewer children dropping a peg or being unable to fasten
buttons.

Other errors of motor control did not show such a clear
pattern of development. These included observations of a lack
of smoothness and fluency in movement and movements that
looked odd. Several Clumsy children were noted to have
movements that lacked smoothness and fluency, especially in
the buttoning task. As mentioned above in relation to the
speed of performance, other studies involving reaching tasks
and sophisticated digital recording methods have revealed a
shorter initial phase and more corrective movements in Clumsy
children compared to their controls (Schellekens et al., 1983;
van Dellen, 1987). It would be interesting to see video
recordings of the childrens' performance alongside these more
detailed movement recordings, to see whether they are
associated with the more jerky movement patterns that were
observed in the present studies. The finding that some aspects
of motor control are resistant to change confirms the findings
for figure drawing reported in chapter five. The finding that
these children produce pictures with jerky, uncontrolled lines
reflects the observations of a lack of smoothness of movement
in the present investigation.

In the present study, there were some children whose movements
could only be described as 'odd'. The possible meaning of this
observation has already been discussed in relation to the way
the children grasp objects. In this case however, it refers to
overall patterns of movement of the arm and hand. The children
for whom this observation was noted displayed movements that
were difficult to describe any more precisely, although it was
clear that their performance was unlike that of normal
children. Once again, these findings are in line with those in
chapter five where it was noted that some of the Clumsy
children produced drawings that incorporated quite bizarre
elements in them. In this study, there was no evidence that
this 'oddness' of movement diminished with age.

Spatial characteristics:

The focus now turns to those observations categorised as spatial errors. Misalignment of the peg with respect to the hole was the most commonly reported observation. In this case, although the children reached the target position, they had difficulty with the accurate and smooth placement of the peg in the hole. It was reported in chapter five that some of these children do have visual perceptual problems and this may be related to their difficulties with this aspect of task performance. If the target position is inaccurately perceived, then it is not possible to transport the peg to the precise target position, resulting in misalignment. However, the results suggested that this error steadily improves with age.

A rather different type of spatial error was observed by a small number of children in the buttoning task. In this case, the children seemed to have more general location difficulties in that they did not move their fingers directly to the button or button hole. Although this observation may be explained in terms of poor visual perception, as above, an alternative explanation concerns an inability to determine the position of their hands in space either in relation to each other or to other objects (ie. the button and button hole). As discussed in chapter two, it seems that Clumsy children do have difficulties in making sense of kinaesthetic information and translating this into movement. In the buttoning task, there may be considerable reliance on kinaesthetic information since the buttons and holes lie vertically on the trunk and may not easily be seen. For these spatial errors no clear improvements with age were found.

Force characteristics:

Several of the Clumsy children were also noted to use excess force in the peg insertion task (when pushing the peg into the hole), suggesting that they may have difficulties in regulating the amount of force in movement. The finding in chapter five, that the Clumsy children had difficulty in drawing lines that met cleanly at junctures, may also reflect

problems of force control. For some children, however, the use of excess force seemed to reflect a strategy that they adopted as the result of another error, misalignment of the peg. That is, when the peg could not be easily inserted into the hole, they tried forcing it in. This observation suggests that some children adopt inappropriate strategies that interfere with performance.

In this study, the observation checklists allowed for the systematic observation and recording of performance and the data from them was used in a number of different ways. While the overall number of errors gave a broad indication of how well or poorly the task was performed, the individual errors pinpointed specific difficulties that the children experienced. The observation of movement errors are thus a useful way to study Clumsy children. It was found that even when their movements were successful in terms of outcome, Clumsy children displayed a range of unusual characteristics indicating that lack of control of the hands takes various forms.

6.5 The role of vision in manipulative skill

6.5.1 Introduction
In the previous section it was reported that Clumsy children experience a range of problems in the performance of familiar manipulative tasks. This section now turns to the question of how these movements are produced, focusing specifically on the role and use of vision in the control of manipulative action.

As noted in chapter two, there are only a few studies that have allowed for an investigation of the role of vision in Clumsy children, one of which was replicated in chapter five. The method employed in these studies has been to compare the nature and extent of differences between Clumsy and control children under conditions in which the availability of visual information is varied. Adopting this methodology with the tasks employed in the previous section, the aim of this section is to expand and improve upon this line of work.

Although it was assumed that all children will have had a considerable amount of practice at both the peg insertion and buttoning tasks, it was hypothesized that the pattern of the problems the children showed would vary, with Clumsy children more affected than controls.

As in the previous section, the number and age range of children employed in this study allowed for the investigation of age effects.

6.5.2 Method
The method was described in section 6.2. In order to investigate the effect of withdrawing visual information on the quality of performance, the results from the NV condition were compared with those from the V condition described in

part one. Although described in separate sections, it should be remembered that the V and NV conditions were actually performed in the same session.

6.5.3 Results

An overall view of performance
a. Speed of performance
In figure 6g the childrens' speed of performance on both the peg insertion and buttoning tasks are shown. Although minor differences are present, the overall picture presented in these graphs is remarkably similar. When statistical analyses using MANOVAs were performed on the time taken to complete each task, this similarity of outcome was indeed confirmed. On the peg insertion task, there were significant main effects of Group ($F=30.23$, $df=1,76$ $p<.0001$), Age ($F=11.12$, $df=3,76$, $p<.0001$) and Condition ($F=153.44$, $df=1,76$, $p<.05$). The following interactions were also significant: Group by Age ($F=3.87$, $df=3,76$ $p<.05$), Group by Condition ($F=19.16$, $df=1,76$ $p<.0001$), Age by Condition ($F=7.27$, $df=3,76$ $p<.0001$) and Group by Age by Condition ($F=3.49$, $df=3,76$ $p<.05$).

Similarly, on the buttoning task, there were significant main effects of Group ($F=31.00$, $df=1,76$ $p<.0001$), Age ($F=7.39$, $df=3,76$ $p<.0001$) and Condition ($F=22.87$, $df=1,76$ $p<.0001$). The following interactions were also significant: Group by Age ($F=4.04$, $df=3,76$ $p<.01$), Group by Condition ($F=15.99$, $df=1,76$ $p<.0001$), Age by Condition ($F=4.15$, $df=3,76$ $p<.01$) and Group by Age by Condition ($F=3.06$, $df=3,76$ $p<.05$).

Thus, in both tasks the Clumsy children performed significantly more slowly than their controls, the younger children performed more slowly than the older ones and Clumsy children were more affected by the removal of vision than normal. Post hoc analyses using Tukey's procedure then revealed that for both tasks, the improvements with age were only significant for the Clumsy group and that the effect of removing vision was particular striking for the youngest

Peg Insertion
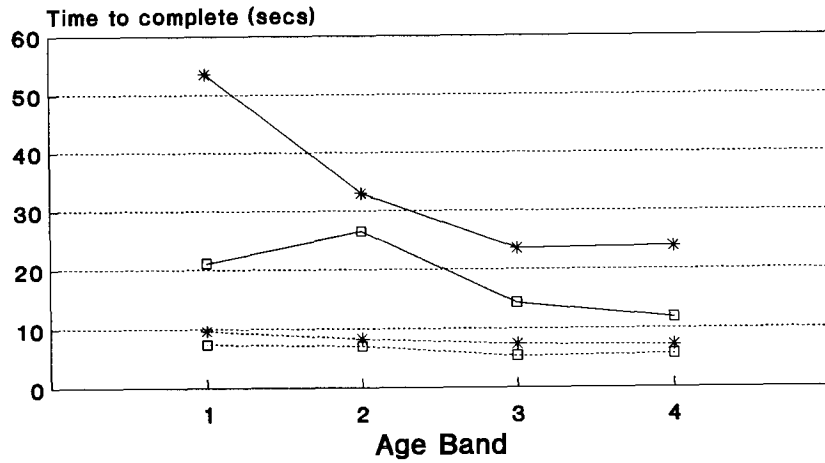
Time to complete (secs)

Age Band

··*·· Clumsy - Vision   ··□·· Control - Vision

—*— Clumsy - No Vision   —□— Control - No Vision

Buttoning

Time to complete (secs)

Age Band
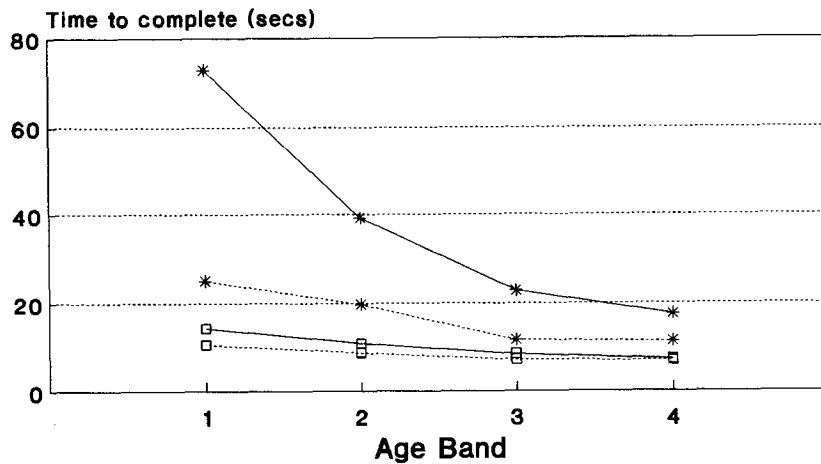
··*·· Clumsy - Vision   ··□·· Control - Vision

—*— Clumsy - No Vision   —□— Control - No Vision

Figure 6g. Time taken to complete tasks in Vision and No Vision conditions

Clumsy children.

b. Quality of Performance

As in part one, the analysis of how the children performed the tasks was begun by examining total number of errors as an overall measure. Group by Age by Condition MANOVAs were conducted for each task. The results are shown in figure 6h and once again suggest considerable similarity between the two tasks.

For the peg insertion task, the analyses revealed significant main effects of Group ($F=57.96$, $df=1,64$ $p<.0001$), Age ($F=8.94$, $df=3,64$ $p<.0001$) and Condition ($F=17.10$ $df=1,64$ $p=.0001$). However, the only interaction to approach significance was Group by Age ($F=2.50$ $df=3,64$ $p<.067$). On the buttoning task, identical analyses revealed a picture more similar to that on speed of performance. Main effects of Group ($F=89.64$ $df=1,64$ $p<.0001$), Age ($F=11.47$ $df=3,64$ $p<.0001$) and Condition ($F=9.07$ $df=3,64$ $p<.005$) and three of the interactions were significant: Group by Age ($F=4.53$ $df=3,64$ $p<.006$); Group by Condition ($F=4.30$ $df=3,64$ $p<.05$) and Group by Age by Condition ($F=3.21$ $df=3,64$ $p<.05$). The Age by Condition interaction approached significance ($F=2.29$, $df=3,64$, $p<.087$). Post hoc analyses using Tukey's procedure once again showed that the effect of removing vision was particular striking for the youngest Clumsy children.

In sum, the results concerning the quality of performance were very similar to the results for completion time for the two tasks. The Clumsy children made significantly more errors than the controls, the younger children were less proficient than older ones and performance was significantly worse when visual information was not available.

Individual Differences

As noted throughout this thesis, the group results are not always representational of the performance of every individual. This was equally true in the present

Peg Insertion

Mean number of errors

```
6 ┤           ✳
  │    ✳
5 ┤
  │           ✱
4 ┤    ✱
  │                    ✱
3 ┤                    ✳
  │
2 ┤    ⊡                         ✳
  │    ⊡      ⊡         ⊡        ✱
1 ┤                    ⊡
  │                              ⊡
0 ┤                              ⊡
  └────┬──────┬─────────┬────────┬──
       1      2         3        4
                 Age Band
```

```
··✳·· Clumsy - Vision          ··⊡·· Control - Vision
─✱─ Clumsy - No Vision         ─⊟─ Control - No Vision
```

Buttoning

Mean number of errors

```
7 ┤
  │    ✱
6 ┤           ✱
  │
5 ┤
  │    ✳
4 ┤           ✳        ✱
  │                    ✳
3 ┤
  │
2 ┤                              ✱
  │    ⊡      ⊡                  ✳
1 ┤    ⊡                ⊡
  │                    ⊡
0 ┤                              ⊡
  └────┬──────┬─────────┬────────┬──
       1      2         3        4
                 Age Band
```

```
··✳·· Clumsy - Vision          ··⊡·· Control - Vision
─✱─ Clumsy - No Vision         ─⊟─ Control - No Vision
```
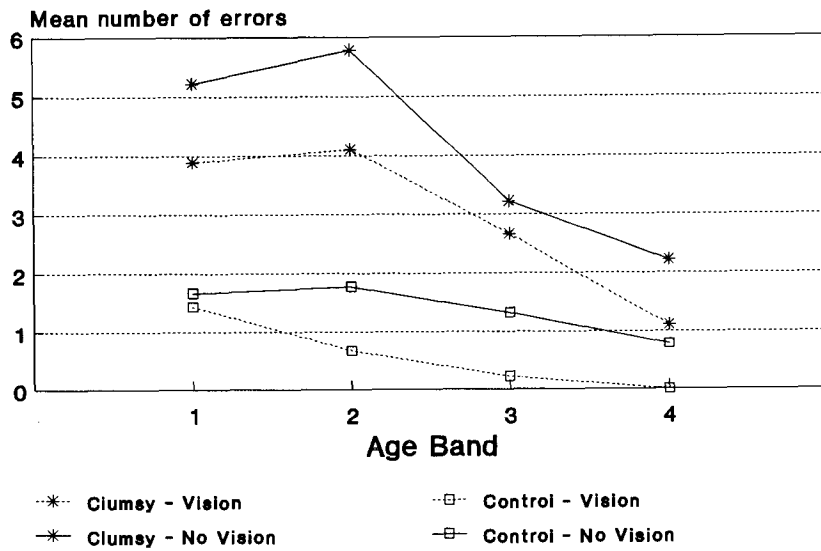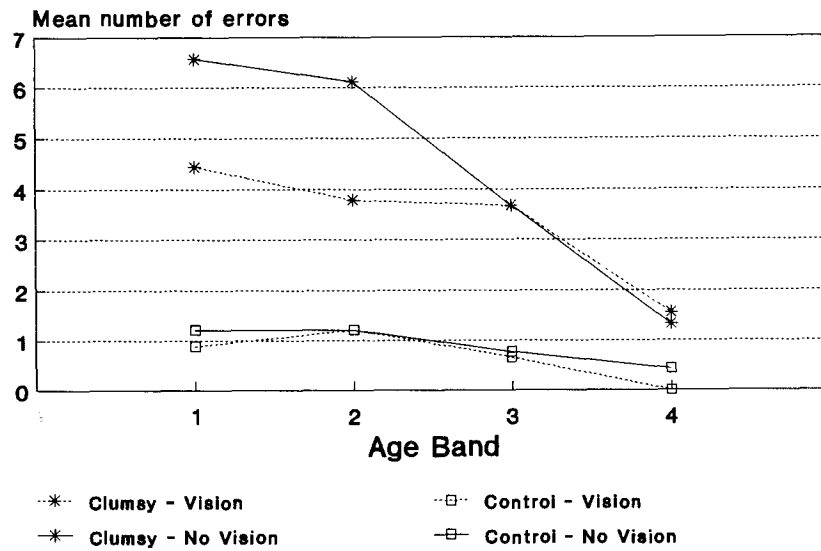
Figure 6h. Mean number of errors in Vision and No Vision conditions

investigation. When the individual data was examined, differences were found in the extent to which performance was affected by the removal of visual information.

In the peg insertion task almost all of the children performed more slowly when vision was not available. However, there were three control children whose performance was unchanged (± 2 seconds). In the buttoning task, although most of the children performed more slowly in the NV condition, there were 10 Clumsy and 12 control children whose performance was virtually unchanged.

There were also individual differences when the data on quality of performance was examined. In peg insertion, most of the Clumsy and control children had more errors in the NV condition. However, there were a few who were better and some whose performance was unchanged.

One of the youngest Clumsy children (subject 1 in table 4.5) showed an obvious deterioration in performance when vision was not available. In the peg insertion task, he took 9 seconds to complete the task with vision but over a minute longer without vision. In addition to performing more slowly, he also displayed eight more errors. He had problems searching for and locating the holes, transferred the peg from one hand to the other, under reached the target, used excessive force and showed additional movements (swaying his body from side to side). However, he did manage to complete the task eventually. The same child was unable to fasten buttons in either the V or NV condition and so was allocated the slowest time from his age group. In his attempt to perform the task he displayed two more errors when vision was not available. In this case his movement lacked smoothness and looked odd.

In contrast, the performance of another Clumsy child (subject 22 in table 4.5) was not so affected by the removal of vision. This nine year old girl completed the peg insertion task in 9.5 seconds with vision and in 20 seconds without. In both

conditions she displayed the same three errors: poor grip, hesitation and excessive use of force. In the buttoning task she was 2 seconds faster in the NV condition and the quality of her performance was rated as better in that she did not show a poor posture as she had done previously.

Characteristics of the Clumsy group

As can be seen in Figure 6h, the removal of vision had relatively little affect on the quality of performance of control children. Consequently, the rest of the results section concentrates only on the Clumsy group.

a. The effect of removing vision on different components of performance

The results for the different components of performance are provided in table 6.8. This shows the number of Clumsy children displaying each error in the V and NV condition. As in part one of this study, the results were first examined in terms of groups of errors that are considered to reflect problems in specific areas of performance.

Motor Control:

The first few items in the table relate to control of the body in terms of posture and grip. Beginning with the effect of removing vision on posture, it can be seen from table 6.8 that slightly fewer children display errors of posture in the buttoning task when vision is removed but there is no change in the peg insertion task.

Although the buttoning task generally revealed more problems of grip for the Clumsy children, the removal of vision did not alter the incidence of observations in either task. This is not surprising since it seems unlikely that children watch the grip configuration when visual information is available. Thus the removal of vision is unlikely to effect this aspect of performance.

Table 6.8. Number of Clumsy children exhibiting each item in the Vision (V) and No Vision (NV) condition. (Bracketed observations and figures apply to only one of the tasks). n=36.

Errors	Peg Insertion		Buttoning	
	V	NV	V	NV
Motor Control:				
Poor posture	5	5	11	9
Poor grip	13	12	21	21
Fingers stiff	4	4	7	7
Change of grip	7	7	2	3
(Difficulty pushing)	-	-	(19)	(18)
(Difficulty pulling)	-	-	(15)	(16)
Movements lack smoothness	5	9	15	19
Movements look odd	8	13	7	20
Hesitation	4	5	1	0
Motor Overflow:				
Exaggerated movements	7	5	5	0
Tapping	4	0	4	4
Additional movements	1	2	0	1
(Associated movements)	(2)	(0)	-	-
Spatial Errors:				
Difficulty locating peg/ button	0	7	4	5
Difficulty locating hole	0	24	8	18
Seeking movements	1	0	1	
(Over reach)	(0)	(1)	-	-
(Under reach)	(0)	(10)	-	-
(Misalignment)	(23)	(11)	-	-
(Misplacement)	(0)	(3)	-	-
Force Errors:				
Excess Force	14	7	0	3
Other Errors:				
Distraction	0	0	2	7
Poor exploration	0	14	9	14
(Transmission)	(1)	(2)	-	-
(Peg dropped)	(7)	(1)	-	-
(Unable to fasten button)	-	-	(2)	(7)
TOTAL	73	123	93	131

- item not applicable to task

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By far the most striking effect of removing vision, however, was observable in the way the children performed the component movements of the two actions. Although their movements generally lacked smoothness, when vision was removed, the number of observations increased substantially. In the buttoning task, many children also had difficulty pulling and pushing the button through the button hole in the NV condition. These observations, however, were no more frequent in the NV condition compared to the V condition.

Motor overflow:
It can be seen that in both tasks there was a decrease in the number of children showing exaggerated movements of the fingers when vision was removed. While these observations are interesting, they are difficult to interpret. It can also be seen that the number of children tapping the peg decreased without vision but in buttoning, the amount of tapping was unchanged. The changes in additional and associated movements were small and inconsistent across the tasks.

Spatial Errors:
It is this type of error that was expected to increase most in the NV condition because spatial information was not available through vision. This was in fact the case in that more children had location difficulties in both tasks and difficulty locating the hole was the most common error in the peg insertion task. In the NV condition no visual information was available to specify the position of the holes. Therefore, in order to locate the holes the children had to rely on memory of their position and/or use other perceptual information, for example some of them used their fingers to feel where the holes were. From the table, it can be seen that in the peg insertion task more children under reached (ie fell short) of the target holes in the NV condition, but there was little change in over reaching.

The only error that showed a dramatic improvement in the NV condition was misalignment of the peg with respect to the

hole, which indicates minor spatial difficulties. The explanation for this result is based on the fact that there was an increase in other errors (location difficulties and under reaching of the hole). These more severe spatial difficulties indicate problems in finding the hole but once it is found, the peg is inserted without misalignment. In contrast, in the V condition, the more severe difficulties are not experienced and the only spatial error is slight misalignment of the peg.

Force errors:

In relation to errors of force control, there was a decrease in the number of children using excess force in the peg insertion task, but little change in buttoning. This improvement in the peg insertion task corresponds with a decrease in errors of misalignment, which, it was suggested earlier may be linked to the force errors.

Other errors:

From the table it can be seen that distraction increased in the buttoning task when vision was removed. It may be that, finding the task more difficult when vision is not available, concentration lapsed. In contrast, no children were distracted from the peg insertion task in either of the conditions.

In the peg insertion task, poor exploration showed a dramatic increase in the NV condition and in both tasks was one of the most common errors in the absence of vision. The high incidence of poor exploration explains why the children had such difficulties in locating the holes in both tasks. Errors of poor exploration were recorded when the children showed inefficient or inappropriate strategies to search for and locate the hole. For example, in the peg insertion task some children moved their hand aimlessly across the peg board rather than actively searching for the holes with their fingers. In the buttoning task one child was seen to search for a button hole near his neck, in a position much higher than the top of the waistcoat.

In terms of the final outcome of performance, more children were unable to fasten the buttons in the NV condition and more children misplaced pegs (ie did not put them in the holes). In this condition, however, there were fewer children who dropped a peg.

As suggested by the figures and the main analyses reported at the beginning of this section, the group results may be qualified by the age of the children. This finding is examined in more detail below.

b. The effect of removing vision for children of different ages

The main analyses indicated that the overall affect of removing visual information was greatest for the youngest Clumsy children. This was examined in more detail by focusing on the results of individual errors. This was achieved by first identifying those errors that changed most in the NV condition which are listed in table 6.9. The number of children displaying each of these errors was then divided according to the four age groups. There were nine children in each age group so, as in the previous section, a direct comparison may be made between them. As can be seen from the table, some errors are more clearly related to the age of the children than others.

Motor control:

In relation to the effect of removing vision on motor control, the first point to note is that the pattern of development does not reflect a simple reduction of the dependence on vision with increasing age. Secondly, it is the 7-8 year old children (those in age group two) whose motor control is most clearly affected by the removal of vision. This finding holds for two rather different observations of poor motor control, a lack of smoothness and movements that look odd, and is consistent across the two tasks.

Table 6.9. Change in the number of Clumsy children in each age group displaying individual errors in the No Vision compared to the Vision condition.

PEG INSERTION	AGE GROUP				
Errors:	1	2	3	4	TOTAL
Motor control: Lack smoothness	+1	+3	0	0	+4
Look odd	-1	+6	0	0	+5
Spatial: Locate peg	+3	+3	+1	0	+7
Locate hole	+7	+7	+6	+4	+24
Under reach	+2	+2	+4	+2	+10
Misalignment	-6	-4	-1	-1	-12
Other: Poor exploration	+7	+4	+2	+1	+14
Peg Dropped	-4	-2	0	0	-6
BUTTONING					
Motor control: Lack smoothness	+2	+4	0	-2	+4
Look odd	+2	+6	+5	0	+13
Motor overflow Exaggerated Mts.	-1	-2	-1	-1	-5
Spatial: Locate hole	+4	+6	0	0	+10
Other: Poor exploration	+4	+1	+1	-1	+5
Cannot fasten	+2	+3	0	0	+5

Age Groups: 1   5-6 years
          2   7-8 years
          3   9-10 years
          4   11+ years

Motor overflow:

The observation that fewer children displayed exaggerated movements when vision was not available was difficult to interpret. From the table it can be seen that there are no substantial age differences in this case.

Spatial errors:

There was an overall increase in the number of children displaying spatial errors when vision was not available. When performance is examined across the age groups, it can be seen that the two youngest groups of children are most affected by the removal of vision in terms of locating the peg and locating the holes in both tasks. Thus, the dependence on vision for the location of targets appears to diminish with age. The number of children having more specific problems in terms of accurately aiming for the target (ie. under reaching) in the absence of vision is fairly consistent across the age groups, although this error is slightly more common for the 9-10 year old children.

Finally, the number of children displaying another spatial error, misalignment of the peg, changed quite dramatically when vision was removed. In this case, however, far fewer children displayed the error in the absence of vision. An explanation for this was provided above and here it can be seen that the reduction is greatest for the youngest children.

Other errors:

Problems of poor exploration were much more common when vision was not available, particularly in the peg insertion task. From table 6.9 it can be seen that the youngest children were most affected in this respect and that there is a reduced dependence on vision with increasing age.

It can be seen that fewer children dropped pegs when vision was not available. The fact that this reduction was only evident for the youngest children simply reflects the fact that they were the only ones to display this item in the V

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condition.

Finally, the effect of removing vision in terms of successful completion of the buttoning task was only evident for the children in the youngest two age groups. They depend on vision to such an extent that without it they are unable to fasten the buttons.

Differences in the task demands

The results presented above suggest that the effect of removing vision on performance depends partly on the requirements of the task. Several differences between the peg insertion and buttoning tasks have already been mentioned. One of these seems particularly relevant to performance without the aid of visual information. This concerns the position of the target in both tasks. The target in the peg insertion task is in a fixed position. In buttoning, however, the waistcoat is free to move and thus the location of the target may vary. This makes the 'aiming' component of the task more difficult.

6.5.4 Discussion

This study has investigated the effects on performance of removing visual information, permitting an examination of the role of vision in the control of manipulative action in Clumsy children. Different aspects of the results are discussed separately below.

The effect of removing vision on overall performance

The investigation began by focusing on the speed of performance on the two object manipulation tasks and the results showed that the children generally performed more slowly when visual information was not available to them.
The interactions between group and condition revealed that the removal of visual information had a differential effect on the Clumsy children, with them being more affected by the removal of vision than the controls.

The study by van der Meulen et al. (1991a) reported in chapter two also measured the effect of manipulating visual information on movement time. Contrary to the findings of the present study, they report that the difference between the groups was only significant when visual information was available. They interpret their results in terms of the Clumsy children taking their movement difficulties into account and thus making more use of the visual information when it is available. These conflicting results may partly be explained by two differences between the tasks. Firstly, their task had to be performed in less than one second. Secondly, in their study, when vision of the hand was removed, target position was still visible.

In the present investigation, the effect of removing vision on the quality of performance was also examined. The results were very similar to those for speed with the number of overall errors displayed being greater when vision was not available. As with the results for speed of performance, there was a differential effect on the Clumsy children.

Both the tasks employed and the main results obtained in the present investigation are comparable to two of the studies described in chapter two. The manual pointing task employed by Jongmans (1989) and von Hofsten and Rösblad (1992) is in many ways similar to the peg insertion and buttoning tasks. All of these tasks involve moving an object held in one hand, to a 'target'. When visual information is not available, information concerning target position is obtained by the hands. Thus, one must have knowledge of where each hand is in order to get the hands together so that the object moves into the target position. Although Jongmans (1989) and von Hofsten and Rösblad (1992) used quite different performance measures to the present investigation (they measured distance from the target), the results that they obtained were remarkably similar. They too found that children generally performed with greater errors when vision was not available and that this effect was greater for the Clumsy group.

There are several possible explanations for these results. One of these concerns the role of vision in Clumsy children. The results suggest that vision plays an important role for Clumsy children and that they need a visual frame of reference to construct a movement. It seems that they depend more on visual information compared to control children so when it is removed they are more severely affected. However, it is difficult to relate this to the general finding that Clumsy children have visual perceptual difficulties. If they have difficulty making sense of visual information, then it is difficult to see why they should depend more on visual information.

A different but complimentary explanation of the results relates to the fact that when vision is not available, the system has to rely on other information to plan and execute movements. As noted in chapter two, the main source of information in this case is kinaesthesis. The findings that Clumsy children perform particularly poorly without vision, suggests that they have difficulty in processing kinaesthetic information, an issue that was discussed at length in chapter two. However, the results from the studies by Jongmans (1989) and von Hofsten and Rösblad (1992) suggest that Clumsy children do not have general kinaesthetic deficits. When the target position is specified visually in their manual pointing task, the Clumsy children are able to guide the hand kinaesthetically (vision of the pointing arm and hand is always occluded). Thus it seems that the difficulty lies in encoding the kinaesthetic information and/or translating it into movement of the other hand.

The suggestion that Clumsy children have problems with the processing of kinaesthetic information helps to explain why vision plays a different role in the performance of these children compared to controls. If they do have kinaesthetic deficits then their dependence on visual information is bound to be greater than normal.

The effect of removing vision on children of different ages

The main results noted above were qualified by the age of the children. That is, younger children rely more on visual information than older children in the performance of manual tasks. Although similar age effects have been found for normal children by von Hofsten and Rösblad (1989), very few studies have specifically investigated age effects in Clumsy children. Of those that do, there is no suggestion that age interacts with visual feedback condition as found in the present investigation. One exception is the study by Hoare and Larkin (1991). In their study, as in the present investigation, the youngest Clumsy children performed particularly poorly when vision not available (in this case the K-K condition of a line-matching task).

The results suggest that age effects are also dependent on familiarity of the task. When a task is 'over-learned' and highly practised (as buttoning is for control children of all ages), then the removal of vision has little detrimental effect. However, when a task is not familiar, as seems to be the case in buttoning for younger Clumsy children, then dependence on vision in the control of manipulative action is much greater.

The role of vision in Clumsy children

In addition to the overall results on speed and accuracy, an examination of the errors from the checklists revealed that vision plays a role in several different aspects of performance in Clumsy children.

Firstly, the results suggest that vision plays a particularly important role in controlling the motor system in Clumsy children. Without vision their movements generally lack smoothness and look odd. In addition, they seem unable to overcome these problems when relying only on kinaesthetic information.

The results from this investigation also suggest that visual information has a particularly important role in Clumsy children in terms of providing them with spatial information. Without vision, the Clumsy children found it particularly difficult to locate the targets, a finding that has been reported in other studies that have specifically measured accuracy in reaching to targets (eg Jongmans, 1989). As was the case for motor control, other sensory systems (kinaesthesis and touch) do not take over the role of locating and specifying target positions sufficiently well.

When vision is not available, children without movement difficulties seem to adopt strategies to furnish them with spatial information. Clumsy children, however, seem unable to adopt appropriate spatial location strategies.

Finally, there is also some suggestion that vision has an important role in focusing attention in Clumsy children, since more of them were found to be distracted from the task when vision was not available. Although problems of attention in Clumsy children have also been noted in other studies (van der Meulen et al, 1991a), this has not previously been linked to a dependence of visual information.

Developmental differences in the role of vision
Despite the small sample sizes of children of different ages in this investigation, there was some suggestion that the role of vision changes with age. The role of vision in relation to providing spatial information was particularly striking for the youngest children in this study. In addition, it was these children who were generally unable to adopt strategies to help them perform the task. Although generally the role of vision in providing spatial information appeared to diminish with age, there was a suggestion that 9-10 year old Clumsy children require vision to locate targets accurately.

One particularly interesting finding that is difficult to interpret is that vision seems to play a particulary important

role in controlling the motor system of Clumsy children aged 7-8 years.

Individual differences in the role of vision

Regardless of age, individual differences have been noted in terms of the extent to which children were affected by the removal of visual information. This was true for every aspect of performance studied in this investigation and similar findings have also been reported in other studies (eg Jongmans, 1989; von Hofsten and Rösblad, 1992). Individual differences in the role of vision and in kinaesthetic processing abilities have important theoretical and practical implications. With regard to the former, they suggest that movement difficulties of the type studied here cannot be accounted for in terms of a unitary deficit. The practical implications of this are that Clumsy children need to be assessed individually without assumptions being made about 'blanket' deficits. Furthermore, it suggests that intervention to help these children overcome their movement difficulties is most likely to be effective if it is geared towards the specific difficulties experienced by the individual.

CONCLUSIONS

7.1 Methodological issues

In the first three chapters of this thesis a number of general issues arising from the existing work with Clumsy children were outlined. As stated in chapter three, the aim of the work in this thesis was to address some of these and expand upon what is already known about clumsiness by adopting a number of different methodologies. Firstly, group studies were complemented with information on individual differences. Secondly, cross sectional studies were followed by longitudinal investigations providing information on children of different ages and also how individual children develop over time. Thirdly, descriptive and experimental approaches to the study of clumsiness were combined, using similar tasks and measures of performance in both.

The tasks employed in this thesis are familiar and appealing to young children and were found to be amenable to control and experimental manipulation. Comprehensive descriptions of performance were obtained using measures of outcome and movement quality. It was found that the latter could be reliably measured using simple techniques and that comparisons could be made across performance on the different tasks.

7.2 Descriptions of manual competence in Clumsy children

In the results sections some findings were presented which were common to both the drawing and other object manipulation tasks. These findings are outlined briefly below:

* Clumsy children generally lack manipulative skill compared to their age peers. Some are totally unable to successfully complete simple manipulative tasks such as button fastening.

* Clumsy children have difficulties at the most basic level of motor control. Their body control is poor in terms of posture and grip and their movements are generally characterised by a lack of smoothness and fluency.

* Clumsy children have difficulty with the spatial aspects of manual tasks. They find it difficult to draw things in proportion, to copy shapes accurately and to aim at targets.

* The manipulative skill of Clumsy children generally improves with age but there is some suggestion that they do not catch up with their peers.

* Motor control difficulties generally seem to persist, although there is improvement in other aspects of performance.

7.3 Vision and manual competence

* Clumsy children have visual perceptual problems as measured by their ability to visually discriminate figures differing in shape.

* The relationship between visual perceptual problems and motor competence in Clumsy children is not clear. There is, as yet, no evidence to support the view that visual perceptual problems are the cause of clumsiness.

* Clumsy children depend more on visual information in the performance of manual tasks than their peers.

* Vision plays an important role in the control of manipulative action in Clumsy children. Vision controls the motor system, provides spatial location information and focuses attention on the task.

* In the absence of vision, Clumsy children are less efficient than controls at using kinaesthetic information in the planning and control of manual tasks.

* The role of vision and ability to use kinaesthetic information in Clumsy children changes with age. Young Clumsy children depend more on vision and are less efficient at using kinaesthetic information than older Clumsy children.

There are considerable individual differences on every dimension studied in Clumsy children. In general terms, there is variation in the severity of their motor impairment, their intellectual ability and the number of non-motor difficulties experienced. More specifically, they vary in the extent to which they have difficulties with particular manual tasks and also in the nature of the problems encountered.

There is also variation in the way that Clumsy children develop over time and the way in which they cope with their difficulties.

Finally, there is considerable variation in their visual perceptual abilities and in the role of vision in performance of individual children. These findings suggest that there is unlikely to be a single source deficit causing the movement difficulties of Clumsy children.

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APPENDIX 1

The clumsy child in school - are we doing enough?

Sheila E. Henderson, Elizabeth Knight,
Anna Losse and Marian Jongmans

APPENDIX 2

Clumsiness in children - do they grow out of it?
A 10-year follow-up study

Anna Losse, Sheila E. Henderson, David Elliman,
David Hall, Elizabeth Knight and Marian Jongmans

APPENDIX 3

**The development of observational checklists
for two object manipulation tasks**

Introduction

As noted in chapter three, a major aim of this thesis was to provide detailed descriptions of the way in which Clumsy children perform everyday manipulative tasks. This was achieved by developing observation checklists for the two tasks chosen, peg insertion and buttoning.

Observation checklists are used during or immediately after the observation of a subject performing a specific task. They generally consist of a list of behaviours and are completed by indicating which, if any, of these were observed during performance. Checklists should provide qualitative descriptions of how the task has been performed and can be used to supplement quantitative data concerning movement outcome, such as speed or accuracy of performance. A major advantage of using checklists over other methods of recording movement quality is that they can be used by researchers and therapists with a minimum of equipment and technological expertise (although it is useful to have a video camera and recorder).

Some existing assessment instruments used with Clumsy children contain checklists. For example, the TOMI contains observation checklists for every task in the test (including three manual tasks for each age band). Although no reliability data has yet been collected for these, they are widely used by clinicians to help them pin point the childrens' difficulties with each task.

The only experimental study with Clumsy children to have employed checklists is that by Kalverboer and Brouwer (1983). As described in chapter two, they use observation checklists to record and describe different aspects of performance on a manipulative task (posting shapes into the appropriate holes in a box).

Thus, checklists do exist which have already been used with Clumsy children. However, for several reasons, it was

necessary to develop new checklists for the two object manipulation tasks that were employed in the present investigation. Firstly, no existing checklists contain items that are relevant to buttoning fastening. Secondly, the content and structure of the checklists for peg insertion and buttoning had to be similar in order for some cross-task comparisons to be made. Thirdly, the checklists had to contain items that would describe the performance of children having difficulties with the tasks.

In the development of the checklists, it was considered important to have a framework to organise the observations and interpret them in terms of different aspects of performance. In the existing checklists used with Clumsy children quite different frameworks have been employed. The checklist items employed by Kalverboer and Brouwer were organised according to two separate frameworks. Firstly, they could be grouped according to their spatio-temporal position in the task. Secondly, they were grouped according to an information processing model. Although the former aids the recording of observations, it is of little help in interpreting their meaning. The latter allows for their interpretation in information processing terms, but the particular model adopted by Kalverboer and Brouwer is concerned solely with response-selection and decision-making processes which are difficult to relate directly to movement.

A quite different model has been adopted in the checklists used in the TOMI (Stott, Moyes and Henderson, 1984) and the Movement ABC (Henderson and Sugden, 1992). Here, the distinction is made between items that relate to control of the body and those that relate to the extent to which the child can adjust to the spatial, temporal and force requirements of the task. This framework is directly relevant to movement and can also be useful for intervention. This framework is the one adopted in the present investigation.

Method

The tasks employed are described in chapter six, together with details of how video recordings were taken of performance.

Editing of the video recordings

The videos were edited to give one tape of peg insertion and one of buttoning. The Clumsy and control children and the Vision and No Vision conditions were randomly arranged on the tapes. Only the preferred hand was used in the analysis of the peg insertion task. If qualitative differences do exist between the performance of the two hands they probably favour the preferred hand. Thus it was noted that these observations may reflect the childrens' optimum performance.

Defining the observations

The first step in the development of the checklists involved the viewing of a sample of the edited video recordings of children by two experienced observers (two students of motor development). They viewed a random sample of 10 Clumsy and 10 control children performing the peg and buttoning task under both the Vision and No Vision conditions. During these viewings they listed a number of behaviours that they observed that could be considered as deviations from the norm that interfered with performance in some way. Following discussion, a number of these behaviours were selected to be included in each checklist. For each of these a definition was written to ensure that they were mutually exclusive.

As far as possible, the observation checklist for the buttoning task is the same as that for peg insertion, thus allowing some comparison to be made across them. However, there are several aspects of the tasks which differ (for example, one hand is used for peg insertion and two for buttoning), making it necessary to include some different items.

The items included in each of the checklists are shown in tables 1 and 2. The framework outlined above was used to

organise the items into different categories, each one representing a separate aspect of performance. In the peg insertion task, for example, the first category refers to body control and the items include poor posture adopted during task performance and the poor grip (immature or weak) used to pick up the peg. Also included is whether the fingers are held stiffly during the grasp or the grasp is adjusted. Finally, characteristics such as smoothness or hesitation prior to placing the peg in the hole are noted.

The second category is also related to body control but here the items indicate an `overflow' of movement. This includes observations such as whether the movement was exaggerated in any way, such as the fingers held widely apart on release of the peg. Also included are observations of movements that are additional to the task itself (such as hitting the peg against the board or transporting it in the wrong direction) and associated movements.

In the third category, `Spatial Errors', any difficulties searching for or locating the peg or hole are noted. Also, observations about the final reach position of the hand are recorded, such as whether the peg was slightly misaligned with respect to the hole, whether it clearly fell short of or overshot the hole. Errors of force control are noted in the fourth category if excess force appeared to be used to push the peg into the hole.

Other observations are recorded in the fifth category. Some of these are concerned with attention and the strategies employed. For example, whether the child is distracted from the task in any way, whether there is poor exploration or transfer of the peg from one hand to the other. Others relate to failure of the task in some way, such as a peg being misplaced (ie if the peg was placed somewhere other than in a hole in the peg board) or dropped.

In order to check the clarity of the definitions, one other observer, a primary school teacher, who was blind as to the grouping of the children, observed the videos and completed a checklist on a sample of ten children across all of the tasks. This resulted in the clarification of some of the definitions.

Checking the reliability of observations

Both observers then completed observation checklists for the performance of a further 20 randomly selected children on both the peg insertion and the buttoning task.

An observation was recorded if it was observed once or more during the performance of the task. It was not possible to count the number of times which each observation occurred as some are continuous eg poor grip, movements looking odd etc. and they have no easily determined start or finishing points.

Inter observer reliability was found to be high (96% for the peg insertion and 90% for the buttoning task for all observation occasions on which two observers agreed regarding whether or not a behaviour occurred).

Table 1. Description of items in observation checklist for peg insertion task

Poor posture	slouches and/or holds head very close to table top
Poor grip	grip looks immature, awkward or weak
Fingers stiff	fingers held stiffly and straight
Change of grip	type of grip changed
Lack smoothness	movements appear jerky
Odd	movements look odd in some way (not just unusually slow or jerky)
Hesitation	hesitates at any time or breaks off a movement which is evidently directed at a certain hole, before the peg touches the block
Exaggerated movements	movements of the fingers are exaggerated during release of the peg
Tapping	taps top of peg after it has been inserted in a hole
Associated movements	associated movements of the non-active arm or hand which occur during picking up, transportation or insertion of the peg
Additional movements	additional movements of the hand, arm or trunk, other than associated movements, that have no observable function in picking up, transporting or inserting the peg
Difficulty locating peg	takes time to locate peg in starting box
Difficulty locating hole	takes time to locate position of holes in peg board
Seeking movements	movements of the hand above the pegs on the table parallel to the surface prior to picking up a peg
Over reach	peg is transported to a position beyond the holes in the peg board
Under reach	peg is transported to a position short of the holes in the peg board
Misalignment	peg is misaligned with respect to the hole in the peg board into which it is attempted to be placed
Misplacement	the final position of the peg is somewhere other than in one of the holes in the peg board eg on the table
Excessive force	it appears that excessive force is used to place a peg in in the peg board
Distraction	interruption in the task-oriented activity, as indicated by either visual orientation or an interruption in the activity
Poor exploration	exploration of peg and/or hole is unusual &/or unsystematic
Transmission	transfers a peg from one hand to the other eg. just prior to insertion
Peg dropped	peg is dropped onto the table and then retrieved

Table 2. Description of items in the observation checklist for the buttoning task

Body Control:	
Poor posture	slouches and/or holds head very close to table top
Poor grip	grip looks immature, awkward or weak
Fingers stiff	fingers held stiffly and straight
Change of grip	type of grip changed
Difficulty pulling	difficulty pulling the button through the hole
Difficulty pushing	difficulty pushing the button through the hole
Lack smoothness	movements appear jerky
Odd	movements look odd in some way (not just unusually slow or jerky)
Hesitation	hesitates at any time or breaks off a movement
Motor Overflow:	
Exaggerated movements	movements of the fingers are exaggerated during manipulation of the button or button hole
Tapping	taps button
Additional movements	additional movements of the hand, arm or trunk, other than associated movements, that have no observable function in the task
Spatial Errors:	
Difficulty locating button	takes time to locate button
Difficulty locating hole	takes time to locate button hole
Misplacement	button is placed in incorrect hole
Force Errors:	
Excessive force	it appears that excessive force is used when fastening the button
Other Errors:	
Distraction	interruption in the task-oriented activity, as indicated by either visual orientation or an interruption in the activity
Poor exploration	exploration of button and/or hole is unusual and/or unsystematic
Unable to fasten	child is unable to fasten the button