PERCEPTUO-MOTOR COMPETENCE IN PREMATURELY BORN CHILDREN AT SCHOOL AGE: NEUROLOGICAL AND PSYCHOLOGICAL ASPECTS

by

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This thesis is dedicated to all children who so willingly and enthusiastically participated in this study:

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ABSTRACT

This thesis focuses on perceptuo-motor competence in children born prematurely. The cohort, now 6 years of age, was highly selected and consisted of 183 children whose early cranial ultrasound appearance was well documented. In the literature review issues regarding the detection and classification of brain lesions, the outcome of follow up studies, and the description, identification and sub-grouping of children with perceptuo-motor problems are discussed. This is followed by an outline of the study undertaken and the results obtained.

Overall differences in the performance on the neurological, perceptuo-motor, cognitive, behaviour and self-concept measures between the premature and reference groups are described. Prematurely born children showed more minor neurological signs and were less competent in age-appropriate perceptuo-motor tasks. Cognitive ability was generally lower in this group, but no differences with respect to the behaviour and self-concept measures were found.

The relationship between early brain lesion and later perceptuo-motor competence was explored. Major haemorrhagic and/or ischaemic lesions were related to poor outcome. The prognosis of children with minor haemorrhagic and/or ischaemic lesions was more favourable although these children are clearly at an increased risk for more subtle perceptuo-motor problems as they grow up.

The analyses suggested that among the group of children with perceptuo-motor problems six separate sub-groups existed. In addition to two sub-groups whose profile showed either average or below average performance across tasks, there were four sub-groups who showed specific problems with dynamic or static balance, ball skills or constructional tasks, respectively.

Finally, the characteristics of children with poor constructional ability were examined in more detail. Using performance on a specially for this study designed form board task as an example, it was shown that in addition to quantitative profiles, qualitative descriptions of performance are important to gain a better understanding of subtle perceptuo-motor impairment in individual children.

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INTRODUCTION

Although more premature babies survive today than at the beginning of this century there are still many who die in the neonatal period. During the early 1970s, postmortem examinations on groups of premature children revealed that many had actually suffered brain lesions. Since then, interest in the origins and consequences of brain lesions in premature children has grown.

A major advance in this field of study was the introduction of cranial ultrasonography which made it possible to study the evolution and resolution of brain lesions in vivo. As a consequence, longitudinal studies began to appear in the literature which were designed to investigate the relationship between early brain lesion and later development. So far, the prognosis for these children has been considered up to the age of 3 years but much less is known about their development at school age and beyond.

From the long-term investigations which took place *before* imaging of the infant's brain was common practice we know that many premature children are at an increased risk for later developmental problems. Whereas contradictory results have been reported regarding the children's cognitive ability at school age, most studies agree that performance in the perceptuo-motor domain is affected. The few recently conducted studies which were able to take into account the presence or absence of brain lesions in the neonatal period echo these findings and the word 'clumsiness' appears frequently as a descriptor of many children in this group.

Just as it was thought previously that intelligence was a general ability, there was a time when perceptuo-motor ability was considered to be unidimensional. However, at the time when children with perceptuo-motor problems (irrespective of birth status) became the focus of attention in the 1960s, it was soon acknowledged that the problems they experienced were extremely variable. Since then descriptive and experimental studies have emerged which attempted to document this heterogeneity and to disentangle the mechanisms underlying perceptuo-motor impairment. Within the follow up literature few studies have, however, undertaken an experimental approach to analyze perceptuo-motor

problems in more detail.

The overall aim of the present study was to gain a better understanding of perceptuo-motor development among prematurely born children whose early neurological status was exceptionally well documented. In particular, we set out to compare performance of premature children and reference groups on measures of neurological status, perceptuo-motor competence, cognitive ability, behaviour and self-concept, to study the association between neonatal brain lesions and perceptuo-motor performance at 6 years of age, to investigate the possibility that children with perceptuo-motor problems could be sub-divided into reliable sub-groups and, to conduct an exploratory study of constructional ability among premature children.

CHAPTER 1

Prematurity and brain lesions

1.1 Introduction

The invention of incubators at the end of the 19th century represented a major breakthrough in the development of care for children born prematurely (Wolke, 1991). In fact, before Pierre Budin opened the first premature baby unit in Paris in 1884 such infants were treated in exactly the same way as their fullterm peers and consequently few survived. Even with incubators, however, care for these vulnerable infants was still rather primitive. Only the basic needs of the newborn were provided for such as temperature control and the provision of sustenance. In most cases, this was not enough to ensure survival.

Between 1900 and the middle of the current century, further improvements in care were minor and brought only a small decline in mortality rates and it was not until the introduction of Neonatal Intensive Care Units in the 1960s that a dramatic decline in mortality and morbidity figures occurred (Pape et al., 1978; Stewart et al., 1981). In these units, sophisticated apparatus to assist the child's breathing (ventilators) and other equipment to monitor for example, heart-rate and blood-gas levels became widely available. Also, more effective drugs to control physiological disturbances were developed and the level of expertise among staff increased to provide more effective management of the premature infant. As a result of these improvements, premature infants now have a better chance of surviving.

1.2 A growing interest in brain lesions

Post-mortem examinations on large groups of prematurely born children conducted during the 1970s revealed that many had sustained a brain lesion. These defects were thought to account for one and a half times as many neonatal deaths as were due to congenital anomalies (Machin, 1975).

Long before the advent of technology which enabled us to identify damage to the brain in vivo, pathologists had been describing different types of lesions in premature infants (e.g. Parrot, 1868; 1873; discussed in De Vries, 1987). Since the late 1970s, however, technology has enabled us to identify lesions and follow their evolution and resolution. This advance represented a real revolution in the care of the premature child both in

practical terms as well in relation to research developments.

Perhaps not surprisingly, interest in investigating the development of those infants who survived a brain lesion has grown considerably. So far, however, the bulk of this literature has concentrated on short-term outcome as the first infants with sufficiently well documented brain lesions are only now reaching school age. The opportunity to examine how well children respond to our present demanding environment at school age forms one focus of this thesis.

At the moment, many issues relating to prematurity, its concomitant problems and their relationship to later development remain unresolved. To provide a background to the topics discussed in this thesis, a selection of these are discussed under the following three headings:

1) Brain lesions: their definition, classification and incidence
2) Factors associated with the development of brain lesions
3) Brain lesions in the premature infant: consequences for later development

1.3 Brain lesions: their definition, classification and incidence

Imaging techniques

At first, the most promising method of scanning the brain of premature infants was thought to be X-ray computed tomography (CT). However, there were various problems with using this technique. Despite precautions, it soon became evident that it was dangerous to transport a very ill child from the intensive care unit to the scanning room since complications such as hypothermia could occur. Also, early CT machines produced radiation which was thought to be high enough to be harmful (Pape, 1989). Consequently, CT scans were quickly superseded by ultrasound (US) a method first introduced by Pape et al. in 1979. The major advantage of US over CT scanning was that US equipment could be brought to the bedside (De Vries et al., 1990).

Although the quality of ultrasonography apparatus is still being upgraded in terms of an increasing resolution of the image, it has already proved to be a revolution in the understanding of brain lesions and management of the preterm infant. Figure 1.1 shows an example of an image obtained by ultrasonography.

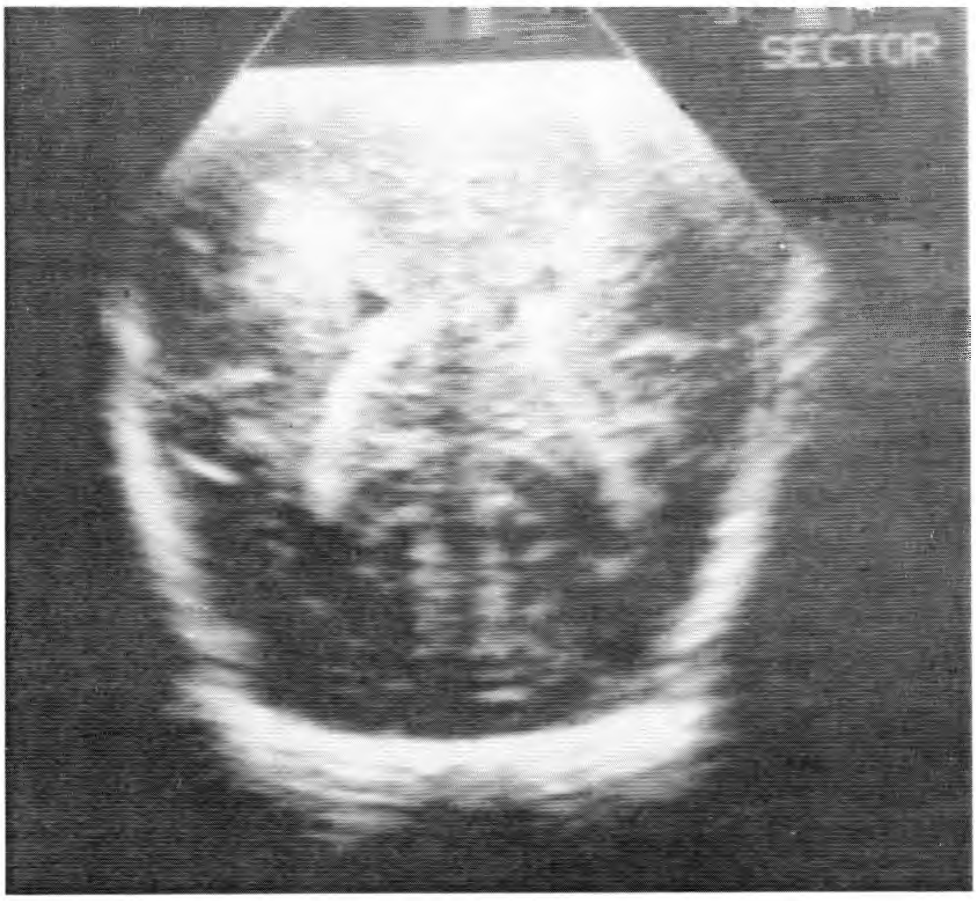


Figure 1.1: Example of an image obtained by means of ultrasonography (coronal view).

Recently, two studies have investigated the reliability of the interpretations of cranial ultrasound scans (O'Shea et al., 1993; Pinto et al., 1988). Both found some disagreements in diagnosis in terms of intra- and inter-observer reliability. However, O'Shea et al. (1993) reported a slightly better result for intra-observer reliability than for inter-observer reliability, suggesting that even though perfect accuracy is difficult to obtain, the best way to minimise interpretation errors is to use one person to classify the ultrasound scans.

Early imaging techniques have revealed two types of brain lesions: one haemorrhagic, the other ischaemic in nature. A brief description of each of these will be presented along with their definition, classification and incidence.

Haemorrhagic lesions

As early as 1929, Ruckenstein and Zollner concluded from postmortem studies of premature infants that blood in the ventricles occurred as a result of a haemorrhage in the germinal matrix (De Vries et al., 1990). However, it was not until a means of detecting lesions in the living brain became available that it was realized just *how many* preterm infants develop haemorrhagic lesions.

From studies of the onset and timing of haemorrhagic lesions we now know that haemorrhages are rarely seen within one hour of birth, but within 72 hours of delivery 80 % are present (Levene et al., 1982). Moreover, they are rarely seen after the first week of life (Partridge et al., 1983; Cooke, 1987). Ninety percent of these haemorrhages occur in the germinal matrix but blood may also extend from there into the ventricular system and sometimes into the brain parenchyma (Casaer et al., 1991).

It is not surprising that a single unifying cause of haemorrhage has not been found. Lack of 'autoregulation' of blood flow seems to be a key mechanism in the cause of haemorrhages. Autoregulation is a term used to describe the maintenance of constant perfusion pressure to the brain in spite of varying arterial pressures. "It is known, in both humans and animals that this autoregulatory mechanism is disrupted and can be abolished by moderate to severe asphyxia" (Pape, 1989; p. 383). Two theories of how haemorrhages occur have been proposed. The first is based on the idea that a haemorrhage is caused by

increased flow or hyper-perfusion in the capillaries. The second suggests that prior to the bleeding, there is first an area of hypo-perfusion which is then followed by subsequent rebleeding. So far, no definite conclusions can be drawn as to which of these models best explain haemorrhages.

Classification of haemorrhagic lesions

There is no doubt that the pioneer in the field of describing haemorrhagic lesions in the living brain was Papile (Papile et al., 1978). Indeed, her four-point grading system summarized in Table 1.1 is still used today (especially in the United States) as a means of grading haemorrhagic lesions documented also by ultrasonography, even though the system was actually based on CT scans.

Table 1.1: Classification system for the extent of haemorrhagic lesions by Papile et al. (1978).

Grade	Description
I	Isolated germinal matrix haemorrhage
II	Rupture of haemorrhage into the ventricle but without ventricular dilatation
III	Rupture of haemorrhage into the ventricle with ventricular distention in the acute phase
IV	Intraventricular haemorrhage with parenchymal involvement

As the body of knowledge on this topic rapidly increased, however, various investigators have either modified Papile's classification system or have introduced a new system altogether (e.g. Catto-Smith et al., 1985; Levene et al., 1982; Rushton et al., 1985; Sostek et al., 1987; Stewart et al., 1983; Scymonowicz et al., 1986; TeKolste et al., 1985). Many of these classification systems have been modified and refined several times. For example, De Vries et al. (1985) added a separate notation to Levene et al's. (1982) system which took into account the amount of blood in the ventricles. This latter classification system is summarized in Table 1.2 and all the haemorrhagic lesions in the prematurely born infants featuring in the present thesis were classified according to this system. In addition, Figure 1.2 illustrates the location of these lesions in the brain.

Table 1.2: Classification system for the extent of haemorrhagic lesions by De Vries et al. (1985).

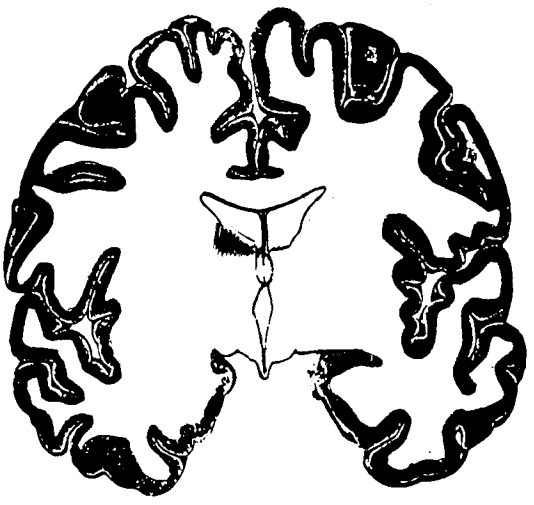
Grade	Description
I	a small haemorrhage restricted to the germinal layer
IIa	a larger germinal layer haemorrhage extending downwards into the basal ganglia
IIb	larger haemorrhages in which a blood clot (cast) distends the lateral ventricles but without involving the parenchyma
III	a haemorrhage extending into the brain parenchyma

As more neuropathological studies are undertaken which shed further light on the nature and possible origin of the brain injury, it has sometimes been suggested that we need to re-define lesions. For example, Volpe (1987) has argued that haemorrhagic parenchymal lesions (a Grade III haemorrhage in the classification of De Vries, 1987) are in fact not an 'extension' of blood from the germinal matrix into periventricular white matter, but instead appear to represent haemorrhagic infarction (an ischaemic brain lesion due to obstruction of blood supply).

Incidence of haemorrhagic lesions

Incidence figures for haemorrhagic lesions vary not only because of the difference in apparatus used to scan the infant's head but also because of variations in the populations studied. Using CT scans, the first figures indicated an incidence of 40-50 % among preterm infants with birthweights less than 1500 grams (Papile et al., 1978). Some years later, figures compiled in London by means of US indicated similar incidence figures for infants less than 1550 grams and/or 32 weeks gestational age (Dubowitz et al., 1981). However, this last group was also able to show that the incidence declines after 32 weeks and again after 35 weeks.

When the incidence of haemorrhagic lesions is further broken down by type, most studies find that a majority of premature infants suffer minor Grades of haemorrhage while the incidence for the more severe Grades is lower (Hawgood et al., 1984). For example, De Vries (1987) observed that out of 676 infants, born between 1982-1986, only 7.5 % developed a Grade IIb or Grade III haemorrhage. Perhaps not surprisingly, it was also



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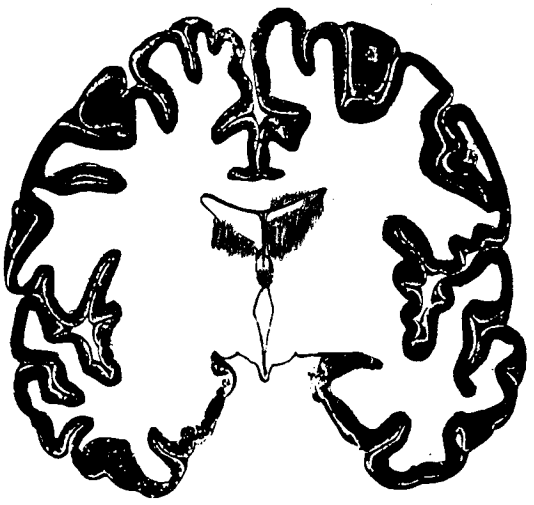

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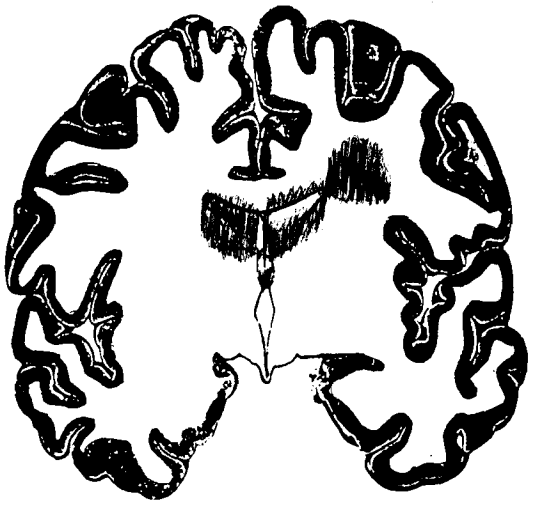


c

Figure 1.2: Location of haemorrhagic lesions in the neonatal brain: Grade I (a), Grade IIa/ IIb (b), and Grade III (c) (coronal view).

found that there is a correlation between birthweight and lesions. For example, Perlman and Volpe (1986) found that the lower the birthweight of the child, the more severe the extent of the haemorrhage.

Regular scanning following the detection of a haemorrhage can show post-haemorrhagic ventricular dilatation. The incidence of this varies depending on definition but has been reported to be as high as 30% (Hawgood et al., 1984; Levene et al., 1982; Pape et al., 1979). The ventricular dilatation may be transient or persistent.

Ischaemic lesions

One of the most recent advances in neonatology has been the detection and classification of lesions in the periventricular white matter. Although this condition was already known to pathologists, it took the development of more sophisticated realtime scanners with higher resolution transducers to identify these lesions.

Compared to fullterm infants, ischaemic lesions in premature infants tend to occur in different regions of the brain. This is due to the different location of the vascular watershed areas between the vessels in the two groups of infants. Whereas at 26 to 36 weeks of brain development in preterm infants the regions sensitive to ischaemic insults are mainly located in the periventricular white matter, in the fullterm infant they lie in the boundary zones between the cerebral arteries and in the white matter under the sulci (Cioni et al., 1992; Volpe, 1987). The lesions found in this region have become known as leukomalacias, with leukomalacia meaning: softening of the white matter (Banker & Larroche, 1962).

A scan on the first day of life may already reveal a lesion in the newborn brain thought to be of ischaemic origin. Indeed, Casaer et al. (1991) reported that in 25% of cases the onset of ischaemic lesions is antenatal. However, more often, ischaemic lesions appear after the first week of life (Sinha et al., 1985; Cooke, 1987; Trounce et al., 1988; De Vries et al., 1990) and like haemorrhagic lesions, can also be associated with later persistent or transient ventricular enlargement (Sinha et al., 1985).

Simplistically said, while haemorrhages are believed to be caused by hyper–perfusion of the vessels in the germinal layer, PVL is believed to be the end product of hypo–perfusion of the arterial boundary zones, i.e. ischaemic in nature. The cause of this hypoxic–ischaemic lesion is believed to be insufficient cerebral oxygen delivery, which is the product of abnormality of both cerebral blood flow and arterial oxygen content (Greisen, 1992). When cerebral oxygen delivery becomes insufficient to meet the demands of the cells for oxygen a chain of events will be triggered resulting in cell death.

Classification of ischaemic lesions

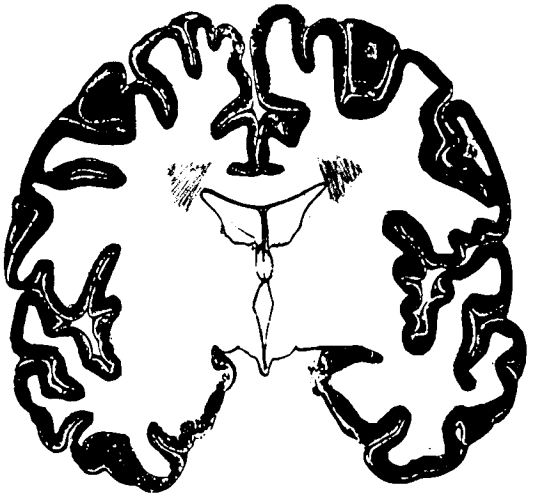
As with the categorisation of haemorrhagic lesions, classification systems of ischaemic lesions (also referred to as leukomalacias) vary although the differences between the classifications are often subtle. In the present thesis all the ischaemic lesions were classified according a system described by De Vries (1987). She divided the leukomalacias into three categories: transient densities (or flares), cystic periventricular leukomalacia, and sub–cortical leukomalacia. Table 1.3 gives a brief description of the three ischaemic lesions as described by De Vries (1987) and Figure 1.3 shows their general location in the brain.

Table 1.3: Classification of the extent of ischaemic lesions by De Vries (1987).

Grade	Description
Flares	areas of increased echogenicity without the evolution into extensive cystic lesions
Cystic Periventricular Leukomalacia	presence of areas of increases echogenicity followed by breakdown into multiple cystic lesions in both hemispheres in the previously dense areas adjacent to the ventricles
Subcortical Leukomalacia	areas of increases echogenicity further away from the ventricles and large cystic lesions identified in the subcortical white matter

Incidence of ischaemic lesions

While it is generally agreed that ischaemic lesions are less common than haemorrhagic lesions (Levene et al., 1983), their reported incidence varies considerably. For example, in a study extending over four years (1982–1985), the incidence of extensive cystic



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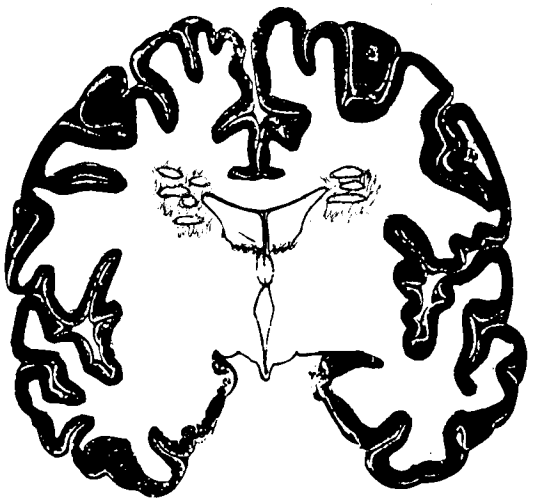

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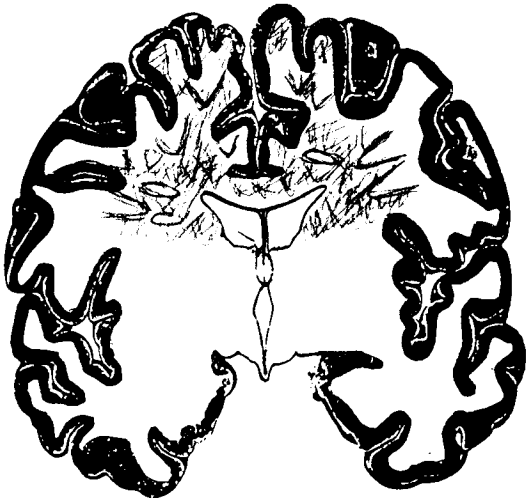

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Figure 1.3: Location of ischaemic lesions in the neonatal brain: flares (a), cystic periventricular leukomalacia (b), and subcortical leukomalacia (c) (coronal view).

leukomalacia (PVL and/or SCL) has been reported to be 2.8% (De Vries, 1987). Levene et al. (1983) reported an incidence of PVL in infants of less than 35 weeks gestation of 7%, while Fawer et al. (1985) found it to be 16% among infants of the same gestational age. Sinha et al. (1985) detected PVL in 18% of the infants they studied of less than 33 weeks gestation. Yet others have found the incidence of ischaemic lesions to be as high as 26% in infants between 25 and 37 weeks of gestation of which half consisted of 'prolonged flares' (Trounce et al., 1988). Although it is possible that this huge variation in reported incidence figures are due to differences in sample selection it is far more likely that they are the result of a difference in definition of ischaemic lesions.

A combination of a haemorrhagic and ischaemic lesion

It is not uncommon that sequential ultrasound pictures reveal that an infant has developed what appears to be both a haemorrhagic and an ischaemic lesion (Rushton et al., 1985). Again, incidence figures vary widely, from 18 % reported by Trounce et al. (1988) in infants between 25 and 37 weeks of gestation to 69 % by Sinha et al. (1985) in a sample of infants born at less than 33 weeks of gestation.

This co-occurrence of lesions of both types with or without an associated ventricular dilatation clearly shows that premature infants with ultrasound abnormalities are not only a heterogeneous population because of the extent of prematurity but also because of the variety in type and extent of lesions that can be found. Moreover, Leviton and Paneth (1990) argue that because of the rapid developments it is not advisable to attempt to group infants according to what appear to be similar abnormalities: "Purely descriptive terms seem more appropriate for the time being" (p. 8). Therefore, the classification systems presented earlier (e.g. those by Papile et al., 1978 and De Vries, 1987) should be regarded as steps towards reaching consensus about clinically useful classifications of brain damage.

1.4 Factors associated with the development of brain lesions

Prematurity and brain damage: a general approach

Leviton and Paneth (1990) describe three possible 'models' of the relationship between prematurity and brain damage. Although they apply these models exclusively to white matter damage, in fact these same models represent current thinking on prematurity and brain damage in general.

The first model sees *both* prematurity and brain damage as a consequence of the same group of antecedents. This model finds support from the fact that various maternal infections seem to be related to giving birth prematurely as well as to an increased risk of brain damage. In contrast, the second model emphasises an apparent reduction in tolerance of prematurely born children to physiological insults such as acidosis and difficulty in regulating cerebral blood flow. According to this model, therefore, brain damage is a consequence of immaturity. Finally, the third model argues that some antecedents already cause brain damage to the child while still in the womb. This, in turn, might promote the premature onset of labour. However, as we do not yet fully understand either the processes governing premature birth or the development of lesions it is neither possible to eliminate any of these alternatives nor to identify the one which provides the best explanation of the relation between prematurity and brain damage.

The research on risk factors for brain lesions can be divided into studies which have found evidence for antenatal factors being related to lesions (model one and three) and those which argue that brain lesions occur after birth as a result of various conditions related to prematurity (model two). Examples of risk factors for each type of lesion will be discussed below.

Risk factors for the development of haemorrhagic lesions

While most people agree that haemorrhages are more likely to develop in sick babies who tend to have more adverse neonatal events, a single unifying cause of haemorrhage has not been found (Pape, 1989).

Sometimes, haemorrhagic lesions are already present at birth. As postulated in Leviton and Paneth's (1990) first and third model, this indicates that certain antenatal factors may be associated with this type of lesions. For example, the incidence of haemorrhagic lesions tends to be higher in infants whose mother had an infection of the amniotic fluid (De Vries et al., 1990). Furthermore, if one of monozygotic twins dies before birth, the surviving twin is at risk of developing a haemorrhage.

Pape and Wigglesworth (1979) concluded from their early pathological studies that the more immature the infant, the greater the likelihood of rupture of immature capillaries of the germinal layer. Other variables associated with haemorrhagic lesions seem to be, among others, hypothermia, the infusion of sodium bicarbonate solution in the first 24 hours, and Respiratory Distress Syndrome (Murton et al., 1985). One of the complications in the latter condition may be pneumothorax which has been shown to lead to an increase in the risk of developing a haemorrhagic lesion (Thorburn et al., 1982; Lipscomb et al., 1981).

Risk factors for the development of ischaemic lesions

Research trying to disentangle factors related to the presence of ischaemic lesions is less abundant than for haemorrhagic lesions. Perhaps not surprisingly, however, it seems that many of the ante-, peri-, and neonatal factors identified as being associated with haemorrhagic lesions are also associated with ischaemic lesions (e.g. ventilatory complications such as pneumothorax). Of the few specific studies published so far, most indicate that maternal antepartum bleeding is an important risk factor in the development of ischaemic lesions (Sinha et al., 1985; Weindling et al., 1985; Calvert et al., 1987). In addition, it seems that the small-for-gestational age (SGA) infant is more vulnerable to hypoxic-ischaemic injury than the appropriate-for-gestational age (AGA) infant (Volpe, 1987). The reasons for this are not yet entirely clear but they may be related to a disturbance in the development of periventricular vascular architecture which is important in the genesis of PVL in certain instances.

1.5 Brain lesions in the premature infant: consequences for later development

Although knowledge in the field of human developmental neurobiology has grown considerably during recent years, the way brain lesions sustained early in life affect subsequent development is not well understood (Casaer, 1993). Similarly, current thinking on whether haemorrhagic and/or ischaemic lesions in the brain of the premature infant might have different effects on later development remains an open question (see e.g. Volpe, 1987 for an extensive review). Finally, an important question which also remains largely unanswered at the moment is why it is that some infants seem to develop 'normally' while other infants show signs of abnormal or delayed development when both appear to have sustained a similar brain lesion. In other words, why is it that in some instances the human central nervous system is capable of partial or full 'recovery' and compensation from these traumatic neonatal events and fails to do so in others? In the past few years, however, the once so popular belief that the earlier an organism suffers brain damage, the less severe the behaviour loss [1] has been questioned (Kolb, 1993). For example, animal experiments have shown that outcome following (induced) cortical lesions at various ages depends on which behaviour is assessed, the type of behavioural test employed and the sex of the animal. However, this principle may still apply among premature infants with similar lesions sustained at different gestational ages.

Apart from obvious inter-individual differences in type and extent of lesion, generally speaking, two characteristics of early brain injury complicate the search for mechanisms which determine later development. First, most instances of brain injury in premature infants are of a diffuse nature. Second, the lesion takes place at a time when the brain is still developing and undergoing several growth spurts. Both of these aspects, of course, also make it difficult to draw upon what we currently know about the consequences of focal injuries to the mature brain.

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[1] *Also known as the Kennard doctrine after Margaret Kennard who in the 1930s studied the effects of cortical lesions on motor performance in monkeys and reported the finding that lesions in infant monkeys had less severe effects on behaviour than similar lesions in adult monkeys.*

Possible morphological defects

In order to understand the origins and possible consequences of lesions sustained in the perinatal period it is important to consider both pre- and postnatal brain development. During development, different brain structures mature at different rates. These include cellular, vascular, and myelinating processes. There are regional differences in speed of growth which means that different parts of the brain are more vulnerable than others. In other words, the timing of adverse events to the brain must play an important role in determining the anatomical location and type of lesion, and thus (together with any 'compensation' that may occur) the final neurological picture (Hagberg & Hagberg, 1993).

The current theory is that in premature infants there are two areas of the brain specifically vulnerable to injury; the germinal matrix layer and the arterial border zones surrounding the lateral ventricles. The germinal matrix layer is the area where the majority of haemorrhagic lesions are observed with the present technology. This small zone close to the lateral ventricular system is the place where all glial cells and neurons of the cerebrum originate (Casaer, 1993). With the help of the radial glial cells the latter cells migrate from this location to a destination within the cerebral cortex and by 20 to 24 weeks of gestation this process is complete (Volpe, 1987). On the basis of these data, therefore, it would seem that a germinal matrix haemorrhage (unless it occurs before 24 weeks of gestation) should not affect neuronal migration (Lyon & Gadisseux, 1991). However, Volpe (1987) has suggested that a germinal matrix or intraventricular haemorrhage may represent a potential hazard to subsequent neuronal processes such as *neuronal organization* (which takes place approximately from the sixth month of gestation to several years postnatal) and *myelination* (which also begins in the second trimester of pregnancy, progresses rapidly after birth and continues into adult life).

Partially in contrast to the view held by Lyon and Gadisseux (1991), Evrard et al. (1992) have speculated that a germinal matrix haemorrhage destroys glial precursor cells in the germinative zone. They suggest two possible consequences of this destructive process. Firstly, cells involved in the formation of myelin (oligodendroglia) are eliminated and/or their migration disrupted, which may potentially result in later impaired myelination. Secondly, cells (astrocytes) ultimately destined for the upper layers of neocortex may be

destroyed and/or their migration disrupted which may, thereby, impair cortical neuronal development. Finally, others have hypothesised that germinal matrix and small intraventricular haemorrhages may create lesions in the head of the caudate nucleus, as well as destroy cells which would otherwise migrate to other subcortical structures such as the amygdala and the thalamus (Pape & Wigglesworth, 1979).

The other area of the brain which seems particularly vulnerable to damage are the arterial border or end zones. These areas have a characteristic distribution in the periventricular region which make them susceptible to a fall in perfusion pressure and cerebral blood flow. It is in these distal fields, i.e. watershed areas that, following an ischaemic insult, PVL occurs (Volpe, 1987). The end product of PVL, of course, will depend upon the size of the initial lesion. Whereas in small lesions, small areas of gliosis [2] may be visible, in large lesions much of the cerebral white matter may be reduced to cystic cavities following massive necrosis (cell death). In addition to loss of brain cells, the actively myelinating glia in the periventricular region may be particularly vulnerable to this ischaemic insult because of metabolic demands. Consequently, ischaemic lesions, like haemorrhagic lesions, may well affect both neuronal organization and myelination (Volpe, 1987). In addition, Evrard et al. (1992) suggest that white matter lesions in premature infants can act as obstacles in the pathway of late migrating glia. This points to a new type of clinico-pathological correlation: the disruption of the topological and ontological relationship constituted by the radial pathway of the late produced astroglia destined for the upper half of the neocortex.

In summary, the specific processes by which haemorrhagic and/or ischaemic lesions in the brain of the premature infant affect subsequent development are still not fully understood but it seems that neuronal organization in the cerebral cortex and myelination are both disturbed by these events. However, these are probably only a few of the morphological changes that may occur and many more aspects of postnatal brain development such as neuronal death or increased differentiation which are equally important in central nervous system growth may eventually differ from the 'normal' pathway of development.

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[2] *Gliosis=increase in volume of (neuro-) gliacells.*

Brain–behaviour relationship

Although the localization of functions in the brain has fascinated psychologists for a long time, what we actually know at the moment about the relationship between brain development, brain function and behaviour is very limited. Since the mid 1970s developmental neuropsychology has established itself as a separate discipline within neuropsychology. It is concerned with the "..elucidation of the brain–behaviour relationship in the developing organism" (Rourke et al., 1983; p. 3). To investigate this relationship many studies within this discipline apply the method of profile analysis whereby a child's performance in a large variety of abilities is examined and compared across tasks (see Chapter 3 for a discussion and examples of this technique). This approach is adopted as it is assumed that the pattern of performance is indicative of whether the functional ability of various regions of the brain is affected or not. Consequently, the search for the organic origin of a specific type of dysfunction has been mainly concerned with studying children whose deficits are highly specific.

One example of this approach can be found in a study by Petrauskas and Rourke (1979). Among a sample of 7 and 8 year old children who were classified as poor readers three subtypes of reading–disabled children were found. The largest group were characterised by their marked difficulties on tasks that were primarily verbal in nature. A second group were found to have difficulties mostly relating to sequencing and a third group had particular difficulties with articulation and graphomotor coordination. Petrauskas and Rourke speculated that these behaviours were expressions of dysfunction of the temporal, the temporo–parieto–occipital, and the frontal regions of the left cerebral hemisphere. As stated before, many of these theories remain highly speculative as they are based mainly on what is known about the adult brain and despite the efforts of neuropsychologists, the body of knowledge on the linkage between neurological and psychological development is only slowly expanding.

The recent emergence of specific scanning techniques such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) now enable us to start investigating the structure–function relationship of the brain in vivo. At the moment, no studies exist yet which have documented maturational stages of the brain among preterm

infants with brain lesions. However, it seems highly likely that preliminary findings of studies on the development of the normally developing brain and subsequent behaviour (e.g. Chugani et al., 1993) will be used as a basis for producing hypotheses about the development and/or plasticity of the central nervous system in (prematurely born) infants with early brain lesions. For example, we might ask whether infants who suffer from a haemorrhage which extends into the basal ganglia show a different pattern of metabolic activity in subcortical brain structures from infants who did not sustain this brain lesion. This and many other questions (for example, the pattern of myelination) are still a matter of discussion and provide the most stimulating cues for future research.

Even in the absence of brain lesions, however, it could be argued that the brain development of prematurely born children may be affected by the fact that they need to survive in what can be called "an unexpected and different environment" (Touwen, 1980; p. 287). Instead of maturing in the relatively protected environment of the uterus, these infants now need to cope with living in a extrauterine environment. The fact that they were born too soon may already be an expression of some underlying problem. The complex interplay between genetic and environmental factors on the one hand and brain development on the other hand, makes it difficult to predict outcome for an individual child. It is all too obvious from clinical data that infants with comparable conditions may develop quite differently.

1.6 Summary

An increasing number of infants survive premature birth and many of these suffer brain lesions in the neonatal period. Today, various imaging techniques are available to visualize these lesions. Ultrasonography is both the most practically useful as well as appropriate for detecting lesions sustained around the time of birth. The origin of such lesions may be either of a haemorrhagic or ischaemic nature, and following the insult may lead to persistent or transient ventricular dilatation. Although there are now several classifications, extreme caution should be taken in 'assigning' infants to a particular category as there is not yet a consensus on their exact characteristics. Moreover, a considerable proportion of premature infants develop both types of lesions.

Two areas in the brain seem particularly vulnerable to injury among prematurely born children. The germinal matrix and the arterial border and end zone in the periventricular white matter have been found to be the locus of injury in haemorrhagic and ischaemic lesions, respectively. The processes following these injuries and their effect on subsequent development remain largely speculative at present. However, new scanning techniques may prove to be promising techniques in examining the relationship between the development of brain structures and emerging behaviour of the infant. Even so, it is still not clear whether the defects in brain structure that are detected by neuroimaging techniques should necessarily be held responsible for an associated developmental problem (Blakemore, 1991 cited in Casaer, 1993).

CHAPTER 2

Follow up studies : A review of the literature

2.1 Introduction

2.2 Outcome of children with or without brain lesions at school age

2.2.1 Is a normal ultrasound scan associated with normal ability at school age?

2.2.2 Is an abnormal ultrasound scan associated with poor outcome?

2.3 Summary

2.1 Introduction

The first long term follow up investigations of the effects of prematurity on later development appeared around 1920 (e.g. Yloppo, 1919). Several of these early studies suggested that premature children were at risk for later difficulties. However, as Benton (1940) pointed out, methodological flaws made their findings very difficult to interpret. For example, most were retrospective in nature, they were based on clinical impressions instead of standardized tests, they did not take account of socio-economic factors, they followed inadequate numbers of premature children and poorly matched control children and, finally involved cohorts of children which were biased in one way or another.

Since then, follow up studies have become more sophisticated and the early '60s heralded prospective studies which have systematically explored the relationship between early risk factors and later outcome (for a review see Kopp & Krakow, 1983). For example, Drillien and her colleagues in Scotland were among the first to prospectively follow premature children until they went to school (Drillien, 1961; 1967; Drillien et al., 1980). Around the same time a large scale study was undertaken in Canada which followed low birthweight children (< 2042 grams) until they reached 6 1/2 years of age (Dunn, 1986). Their results and those of studies that followed further alerted both the medical and educational professionals to the fact that being born prematurely carries with it a risk of later problems, though often subtle in nature.

During the 1970s and 1980s perinatal care improved tremendously. Nevertheless, reports from various countries have observed a rise in the prevalence of cerebral palsy (CP) among very preterm children (e.g. Hack et al., 1979; Stewart et al., 1981). Many medical professionals believe that this is explicable in terms of a constant rate of impairment applied to a steadily enlarged proportion of preterm survivors (Hagberg & Hagberg, 1993): "More worrying is the simultaneous increasing proportion of preterm CP children with severe motor disability and additional neurodevelopmental impairments." (p. 67/68). In addition, it has become obvious that the incidence of more subtle problems is rather higher than had been predicted. Increasingly, studies which follow premature children until school age are noting a variety of subtle difficulties interfering with educational achievement (e.g. Black et al., 1977; Calame et al., 1986; Eilers et al., 1986; Hunt et al.,

1982; Klein et al., 1989; Lefebvre et al., 1988; Lloyd et al., 1988; Nickel et al., 1982; Rickards et al., 1987; Saigal et al., 1990; Sell, 1986; Vohr & Garcia Coll, 1985; Wiener et al., 1968) including difficulty with the execution of age-appropriate perceptuo-motor tasks (e.g. Nickel et al., 1982; Saigal et al., 1990; Siegel, 1982).

In contrast, conflicting results have been reported regarding cognitive functioning. Whereas some studies report a satisfactory level of ability (e.g. Klein et al., 1985; Largo et al., 1990b), others have found a cognitive level below that expected for the children's age (e.g. Robertson et al., 1990; Siegel, 1982; Wiener et al., 1968). Some of these differences can be attributed to differences in perinatal histories between samples. More importantly, however, it now appears that differences in environmental conditions in which the children grow up play a particularly vital role in cognitive functioning at a later age.

Thus, follow up studies even without brain imaging data suggest that apart from the increased risk of developing major impairments, premature children also seem to be at risk for more subtle problems which are likely to affect progress in school and perhaps beyond. It has recently been estimated that the number of published studies which have investigated the development of premature children in the last 30 years is around a thousand (Aylward & Pfeiffer, 1989). From our own search of the literature we have chosen those studies which 1) had good ultrasound data 2) followed the children beyond three years of age, and 3) report adequate data on perceptuo-motor performance.

2.2 Outcome of children with or without brain lesions at school age

This review of studies which investigated the association between the presence or absence of brain lesions in the premature infant and developmental status at school age is divided into two sections. First, we will specifically deal with the outcome of premature children in whom no abnormalities of the brain could be detected by means of ultrasonography in the neonatal period and then we will discuss the outcome of premature children who were diagnosed as having sustained a brain lesion. The main emphasis in each section will be on findings related to perceptuo-motor ability while other aspects of development such as cognitive ability and behaviour are dealt with in less depth.

A search of the English-language literature revealed 13 studies which prospectively investigated the relation between the presence or absence of early brain lesions and outcome in children 4 years or older. Among these studies, 9 used Ultrasound (US) imaging only, 3 identified lesions by means of a Computed Tomography (CT) scan, and one study used either CT or US. Table 2.1a summarizes the sample characteristics and results of studies which used US and Table 2.1b does the same for studies which employed CT imaging. As it is generally agreed that CT is a technique which is less sensitive for detecting lesions in the white matter such as periventricular leukomalacia especially in the first weeks of life (Cioni et al., 1992; Volpe, 1992), this review will concentrate on the 9 studies which used US imaging.

Table 2.2 provides an overview of the assessments included in each study. From this Table, it can be seen that there is some variation in the assessments included in the studies. However, all investigated the children's neurological status, fine and gross motor skills, and cognitive functioning. Outcome in other areas of development such as behaviour have been less extensively reported. Also, the amount of detail on outcome on measures of, for example, motor competence or cognitive ability varies considerably between studies. Whereas some give a detailed account of performance at an item level (e.g. Marlow et al., 1989), others do not attempt to go beyond describing global levels of outcome (e.g. Van de Bor et al., 1993). In the discussion that follows, the question of how prematurity affects later development when no abnormalities were detected on the ultrasound scans precedes a discussion of the association between an abnormal ultrasound scan and outcome.

Table 2.1a: Prospective studies of premature children with or without brain lesions using Ultrasonography.

Author(s)	Imaging technique	Study group N (% of original cohort *) year	N with lesion N without lesion	Control group N	Age at follow-up (years)	Results
1. Cooke 1987	US 5 / 7.5 MHz (mechanical sector)	524 (96%) BW < 1501 grams 1980–1984	with 191 without 333	-	2–5	-incidence of impairment for 'early' lesions: normal scan 5.7%; prolonged flare 7.7%; Grade I haemorrhage 19.2%; Grade II haemorrhage 41.1%; Grade III haemorrhage 71.9% -incidence of impairment for 'late' lesions: normal scan 8.6%; VD 20%; PVL 52.9%; porencephalic cyst 78.1%
2. Costello et al. 1988	US 5 / 7.5 MHz (linear-array)	171 (97%) GA < 33 weeks 1979–1981	with 75 without 96	47 GA 38–40 matched on age, gender same hospital	3–6	-incidence of major or (minor) impairment: normal scan or uncomplicated PIVH 7% (14%); VD 33% (17%); hydrocephalus or cerebral atrophy 56% (13%)
3. Fawer and Calame 1991	US 5 / 7.5 MHz (mechanical sector)	93 (83%) GA < 35 weeks 1982–1984	with 42 without 51	-	5	-incidence of major handicap: isolated PVH (7%); VD with hydrocephalus (25%); extensive PVL (75%) -small focal PVL: increased risk for more neurological signs, and poor motor coordination
4. Ford et al. 1989	US no specifi-cations given	26 (76%) BW < 1501 grams 1979–1980	with 9 without 17	-	5–6	-incidence of neurological abnormality: normal scan (12%); IVH with VD (100%; n=1); parenchymal haemorrhage (60%) -no correlation severity of lesion and visual-motor ability
5. Levene et al. 1992	US 7.5 MHz (mechanical sector)	153 (97%) BW < 1501 grams 1984–1985	with 89 without 64	144 classroom	5	-incidence of cerebral palsy: normal scan 2%; GMH-IVH 4%; prolonged flares 8% -children with both GMH-IVH and prolonged flares worst of all groups on manual dexterity tasks of Movement ABC Test -birthweight best predictor of motor coordination N.B: children with parenchymal haemorrhage or cystic PVL excl.

* infants discharged from the NICU; US=ultrasound; BW=birthweight; GA=gestational age; VD=ventricular dilatation; PVL=periventricular leukomalacia; (P)IVH=(peri-)intraventricular haemorrhage; GMH=germinal matrix haemorrhage.

Table 2.1a: ..continued

Author(s)	Imaging technique	Study group N (% of original cohort *) year	N with lesion N without lesion	Control group N	Age at follow-up (years)	Results
6. Marlow et al. 1989	US 5 MHz (mechanical sector)	55 (72 %) BW < 1251 grams all mainstream school 1980-1981	with 22 without 33	53 classroom matched age and gender	6	-VLBW children more minor neurological signs, poorer on total score and 7 items of the Movement ABC Test, lower IQ, and more adverse behaviour problems than controls -no association between presence of lesion in neonatal period and Movement ABC Test score at 6 years -low 5 min. APGAR score, neonatal neurological abnormality and neonatal septicaemia associated with poor coordination
7. Marlow et al. 1990	US ?	6 (100%) female sextuplet BW < 1600 grams 19??	with 0 without 6	-	5	-no focal neurological abnormalities, 4 girls showed 2 or more minor neurological signs, 3 girls poorly coordinated, all IQ scores within normal limits, mother noted high incidence of behaviour problems
8. Sostek in press	US 5 MHz (real-time scanner)	75 (?) BW < 1751 grams 1979-1983	study 1: with 46 without 29 study 2: without 38	study 1: - study 2: 42 fullterm age and SES	4-5	study 1: -children with IVH and VD or parenchymal haemorrhage poorer on tests of cognition, alphabet recitation, school readiness, and visual shape matching compared to those with minor haemorrhage or no lesion; minor haemorrhage group poorer than no lesion group only on receptive vocabulary N.B: children with PVL excluded from the study study 2:-children without IVH poorer on some McCarthy scales, one leg balance, visual-motor integration, school readiness, visual shape matching and behaviour

* infants discharged from the NICU; US=ultrasound; BW=birthweight; VLBW=very low birthweight; VD=ventricular dilatation; PVL=periventricular leukomalacia; (P)IVH=(peri)intraventricular haemorrhage; SES=socio-economic status.

Table 2.1a: ..continued

Author(s)	Imaging technique	Study group N (% of original cohort *) year	N with lesion N without lesion	Control group N	Age at follow-up (years)	Results
9. Van de Bor et al. 1993	US 5 MHz (mechanical sector)	304 (100%) GA < 32 weeks 1983	with 70 without 234	-	5	-incidence of disability or (handicap): no lesion 11% (13%), subependymal or IVH (without VD) 16% (26%), IVH with VD or parenchymal haemorrhage 6% (29%) -after correction for six possible confounding variables, mild PIVH carried an increased risk for poorer neurodevelopmental performance N.B: 3 children with VD excluded from the analyses and PVL not detected

* infants discharged from the NICU; US=ultrasound; GA=gestational age; VD=ventricular dilatation; PVL=periventricular leukomalacia; (P)IVH=(peri-)intraventricular haemorrhage.

Table 2.1b: Prospective studies of premature children with or without brain lesions using Computed Tomography.

Author(s)	Imaging technique	Study group N (% of original cohort *) year	N with lesion N without lesion	Control group N	Age at follow-up (years)	Results
10. Leonard et al. 1990	CT or US no specifications given	129 (67%) BW < 1251 grams 1977-1982	with 45 without 84	-	4-6	-incidence of neurological abnormality: normal scan 5%, IVH with VD or parenchymal haemorrhage 21% N.B: data missing on 7 children with lesion
11. Lowe and Papile 1990	CT	38 (19%) all AGA BW < 1501 grams no handicaps 1977-1979	with 11 without 27	22 fullterm matched on age, gender, race and SES	5-6	-whole group of premature children poorer than controls on cognition, reading and tactile perception -on combined scores of cognition, reading, visual-motor ability and tactile perception: children with lesions poorer than children with no lesions (not on individual tests)
12. Williams et al. 1987	CT	35 (83%) BW < 1501 grams 1978	with 13 without 22	-	4-6	-10 children in lesion group (77%) some abnormality: clumsiness, speech problems or spastic diplegia (n=2) compared to 18% in no lesion group (no neurological abnormality) -lesion group only poorer on Motor Scale of McCarthy
13. Williamson et al. 1983	CT	29 (83%) BW < 2001 grams 1977-1978	with 29 without 0	-	2-5	-incidence of cerebral palsy 38%; mild to moderate cognitive impairment in 52%; 12 children needed special education (41%) at the age of 3; Grade of haemorrhage significantly associated with neurological outcome

* infants discharged from the NICU; CT=computed tomography; US=ultrasound; BW=birthweight; AGA=appropriate-for-gestational age; VD=ventricular dilatation; IVH=intraventricular haemorrhage; SES=socio-economic status.

Table 2.2: Assessments included in studies using Ultrasound imaging.

Assessments	Studies (see Table 2.1a)								
	1	2	3	4	5	6	7	8	9
Neurological status and perceptuo-motor competence									
Neurological/developmental status									
Amiel-Tison et al. (1983)		*							
Amiel-Tison and Grenier (1986)		*	*						
Touwen (1979)			*			*			*
Baird and Gordon (1983)				*			*		
Fog and Fog (1963)						*			
unspecified	*				*	*			
Motor competence									
Bax and Whitmore (1973)		*							
TOMI (Stott et al., 1984)					*	*	*		
DeGangi-Berk (1983)								*	
Merrill-Palmer (Stutsman, 1931)		*							
Graphic skills									
Frostig et al. (1961)		*							
VMI (Beery, 1982)				*				*	
Visual discrimination									
Visual discrimination								*	
Background information									
Cognitive functioning									
DST (Frankenburg et al., 1973)	*								*
McCarthy Scales (1972)		*	*					*	
PVT (Dunn and Dunn, 1981)								*	
WPPSI (Wechsler, 1967)				*	*	*			
BAS (Elliott et al., 1983)							*		
Tizard et al. (1988)					*				
alphabet recitation								*	
Behaviour									
Rutter Scale for parents (1965)							*		
Rutter Scale for teachers (1967)		*							
Check List (Richman et al., 1982)		*							
Hadders-Algra et al. (1988)			*			*			
own compilation of items								*	
Demographic variables/history									
Medical history						*	*		
SES (Parental occupation)			*			*	*	*	
Racial composition								*	

2.2.1 Is a normal ultrasound scan associated with normal ability?

Depending on the method of assessment, approximately 50% of children born prematurely never show an abnormality upon sequential ultrasound examination. Although it may well be that these children suffer from other medical conditions related to prematurity (e.g. Respiratory Distress Syndrome or metabolic disturbances) which influence subsequent development, this group of children are of interest in studying the effects of prematurity independent of a demonstrable brain lesion.

Although all 9 studies summarized in Table 2.1a report on the later outcome of premature children with normal ultrasound scans, various difficulties arise when interpreting their results. For example, Costello et al. (1988) decided to combine the results of children with normal scans and those with isolated haemorrhages – admittedly, after they could not detect any statistically significant differences between the groups. Similarly, Ford et al. (1989) comment that 10 children whom they grouped under the heading 'normal scan', had in fact developed transient or persistent ventricular dilatation during the first year of life. Furthermore, 5 studies contrasted performance of the premature children with normative data leaving only 4 studies which performed a direct comparison between their subjects and a control group (Costello et al., 1988; Levene et al., 1992; Marlow et al., 1989; Sostek, in press). Finally, Levene et al. (1992) did not assess all children in their cohort on the presence or absence of minor neurological signs. Only those children who were "..thought to be neurologically abnormal when seen at 18 months, including those who showed dystonia; all children with the appearances of cystic PVL or prolonged flare in the neonatal period; and all children who had a high TOMI score above 10, suggesting the possibility of a definite neurological abnormality." (p. 688), were assessed by a paediatrician at 5 years of age on a complete neurological examination. Since all other testing in this study was carried out by a different observer it is, therefore, difficult to be absolutely certain about the neurological status of the remaining children in the cohort.

One follow up study that is of particular interest examined a female sextuplet (Marlow et al., 1990). These girls did not only share the same preconceptional and prenatal environment but, more importantly, the children grew up in the same family, neighbourhood and attend the same school. This means that the rearing environment

which has been so often described as playing a crucial part in later development (e.g. Drillien & Drummond, 1983) is likely to affect the development of these children in the same way, therefore giving the unique opportunity to examine long term development of preterm children with no evidence of a brain lesion.

From cerebral palsy to 'clumsiness'

It is known that within the population of prematurely born children the severity of perceptuo-motor difficulties can range from identifiable CP to lesser problems often described as 'clumsiness'. Whether children born prematurely who have no evidence of a lesion in the neonatal period will never develop CP is difficult to answer at this moment. On the one hand, there is some evidence that a normal scan is a good predictor of absence of major movement disorders at school age. None of the 51 children with normal scans studied by Fawer and Calame (1991) nor any of the sextuplets studied by Marlow et al. (1990) developed a major neurological abnormality.

On the other hand, 10 out of 333 children (4%) with no (early) lesion identified in the cohort studied by Cooke (1987) developed either a diplegia (n=6), hemiplegia (n=2) or quadriplegia (n=1), one out of the 64 children (2%) from Levene et al.'s cohort (1992), was diagnosed as having CP, and two out of 17 children (12%) categorized as having a normal scan in the study by Ford et al. (1989) were classified as neurologically abnormal. The abnormalities at 5 years of age of children in the last study were described as " .. hearing loss, seizures and diplegia" (p. 1187). However, the problem with this particular study is that some of the children had transient or persistent ventricular dilatation in the first year of life a point which the authors fail to discuss in relation to the children who developed CP. Similarly, Costello et al. (1988) found that 7% of the combined group of children with normal scan/uncomplicated haemorrhage developed major impairments at school age including CP, but failed to distinguish between the children with normal scans and those with uncomplicated haemorrhages.

Some of the 9 studies reviewed also included assessments which were designed to identify those children whose movement difficulties could not be classified as CP but were nevertheless significant in terms of every day life functioning. Items in these assessments are designed to evaluate performance on age-appropriate fine and gross motor tasks which

can be described as 'functional measures'. This distinguishes them from certain items in classical neurological examinations such as the knee reflex which are thought to detect damage to the underlying structures.

Three out of the 9 ultrasound studies administered the Test Of Motor Impairment (TOMI). All 3 found that premature children with a consistently normal ultrasound scan in the neonatal period were performing more poorly on the items of the TOMI when compared to their fullterm peers. First, Marlow et al. (1989) found a combined group of preterm children with and without lesions to be significantly poorer in their performance on the total score as well as 7 of the 8 individual items of the test as compared to a group of classroom controls. Secondly, Marlow et al. (1990) report that the total scores of a female sextuplet on the TOMI ranged from 1 to 7. Compared to a peer group, four of the girls achieved below their expected age level although none of them could be regarded as extremely incompetent in motor skills. Thirdly, the 64 children with normal scans participating in Levene et al.'s (1992) study obtained a median total score of 2.25, and the control children a median score of 1 on the TOMI. Unfortunately, the authors do not report whether this was a statistically significant difference. However, as the scores among the preterm children ranged from 0 (lowest score; good coordination) to 16 (highest score; poor coordination) and those of the classroom controls from 0 to 8, this indicates that at least some premature children with normal scans were found to perform below the level expected for their age on the motor tasks.

Using the Motor Scale of the McCarthy, Costello et al. (1988), Fawer and Calame (1991) and Sostek (in press) also found that prematurely born children with normal scans obtained the lowest mean score. Despite the fact that this difference did not reach statistical significance when the premature and control children groups were compared (Sostek, in press), this trend seems too consistent to be ascribed to mere chance. In addition to the McCarthy Scales, Sostek (in press) administered the DeGangi-Berk Test of Sensory Integration. On this measure of gross and fine motor competence she reported a difference between preterm children without a lesion and their fullterm controls particularly in the area of balance.

Of the studies listed in Table 2.2, three incorporated assessments of perceptuo-motor functioning that were rather more specific than assessments like the TOMI and McCarthy. Two studies employed the Developmental Test of Visual-Motor Integration (Ford et al. 1989; Sostek, in press), a test of graphic ability which requires the child to copy a number of shapes of increasing complexity. Both studies found that the children had great difficulty with this task. Ford et al. (1989) reported that 12 out of the 17 children scored more than 1 SD below the mean on this test. Similarly, Sostek (in press) reported that premature children without a lesion were significantly poorer at copying than fullterm children of the same age. In addition, Sostek (in press) found that premature children with normal scans have problems of visual perception in addition to perceptuo-motor difficulties.

On a quite different measure of graphic skills, Costello et al. (1988) found children with normal scans/uncomplicated haemorrhages to be equal to control children on a tracing task requiring the child to draw a continuous line between two printed lines at three levels of difficulty. This suggests that as far accuracy of drawing is concerned it is not control of hand movement which is the problem for premature children.

Associated problems

Cognitive functioning

In contrast to their performance in the perceptuo-motor domain, preterm children without a lesion do not seem to be at an increased risk for cognitive impairment at school age. Using a variety of tests, such as the McCarthy Scales, WPPSI and the BAS, all 9 studies show that the cognitive abilities of premature children with normal scans are very close to the standardised mean. Some mean scores even suggested a slightly high average performance at school age. However, it should be noted that these estimates of cognitive ability may be rather optimistic since it has been shown that over a forty-year period the mean IQ of the North-American population has increased several points (Flynn, 1984). That is to say that a mean of 100 is nowadays perhaps not the correct yardstick any more. The only way to avoid too optimistic conclusions is, therefore, to test a control group at the same time.

Only two studies compared performance of a control group and preterm children without

a lesion on a test of cognitive functioning. Sostek (in press) found that the mean GCI scores of the McCarthy Scales for control children was indeed higher than that of the premature children (112 and 106, respectively) but this difference did not reach statistical significance. Neither was there a difference on the Vocabulary Scale score of the WPPSI between children without lesions and their classroom controls in the study by Levene et al. (1992).

Behaviour

There is no agreement in the literature on whether preterm children with a normal scan are comparable to fullterm children in their daily behaviour. While Costello et al. (1988) did not find any difference between ratings of parents of children with normal scans or fullterm control children, Sostek (in press) found observers to judge them as significantly more active and more easily distractible during the assessments. Moreover, Fawer and Calame (1991) found 13 children (25%) without lesions to have either an attentional deficit or other behavioural disorders.

The mother of the sextuplet examined by Marlow et al. (1990) completed the Rutter behaviour questionnaire. In general, a total score of 13 or more indicates that the child is perceived as having a behaviour problem. The mother's answers to the questions were such that 3 of the 6 girls fulfilled this criteria. However, in this case it may well be that the exceptional circumstances in this household made the mother perceive the children in a different way from parents of other premature children.

2.2.2 Is an abnormal ultrasound scan associated with poor outcome?

Eight of the 9 studies reviewed here included premature children who had sustained a brain lesion early in life. The data they presented are therefore relevant to the question of whether the presence of a lesion in the neonatal period is associated with poor performance at school age. Table 2.3 summarizes how each of the studies classified the lesions. From this Table it can be seen that none of the studies encompass the same range of lesions. This is partly due to the fact that not only different apparatus were used to detect brain lesions but there were also differences in how the images were interpreted and classified. For example, Costello et al. (1988) used linear array equipment with low

Table 2.3: Classification of lesions in studies using Ultrasound imaging.

Author(s)	Classification	N
1. Cooke 1987	a) early lesions (first week of life)	
	-flare	13
	-subependymal haemorrhage	73
	-intraventricular haemorrhage	73
	-parenchymal haemorrhage or extension	32
	b) late lesions (second week onwards)	
	-persistent ventricular dilatation	40
	-periventricular leukomalacia	34
	-porencephalic cyst	32
2. Costello et al. 1988	-uncomplicated periventricular haemorrhage	41
	-ventricular dilatation	18
	-post-haemorrhagic hydrocephalus	4
	-cerebral atrophy:	
	unilateral cysts	3
	unilateral cysts and hydrocephalus	3
	general atrophy	6
3. Fawer and Calame 1991	-isolated haemorrhage: subependymal	9
	intraventricular	6
	-post-haemorrhagic ventricular dilatation	3
	-persistent echogenicities/cystic PVL:	24
	additional 1) subependymal/intraventricular haemorrhage	(19)
	2) small focal PVL	(16)
4. Ford et al. 1989	-subependymal haemorrhage	3
	-intraventricular haemorrhage with ventricular dilatation	1
	-intraventricular haemorrhage with parenchymal involvement	5
5. Levene et al. 1992	-germinal matrix-intraventricular haemorrhage	54
	-prolonged flares	13
	-both germinal matrix-intraventricular haemorrhage and prolonged flares	9
6. Marlow et al. 1989	-subependymal haemorrhage	10
	-intraventricular haemorrhage	8
	-parenchymal haemorrhage	2
	-persistent parenchymal changes	7
8. Sostek in press	-subependymal or intraventricular haemorrhage	21
	-intraventricular haemorrhage with or without parenchymal involvement	25
9. Van de Bor et al. 1993	-subependymal or intraventricular haemorrhage	50
	-intraventricular haemorrhage with or without parenchymal involvement	17

resolution transducers and were, therefore, less likely to detect lesions occurring in the white matter (Casaer et al., 1991). Consequently, information on school age performance of children with ischaemic lesions such as cystic periventricular leukomalacia or prolonged echodensities surrounding the ventricles is less abundant than on children with varying Grades of haemorrhage. Another reason why our lack of knowledge of the long term outcome of children with ischaemic lesions is less extensive is that the incidence of

this type of lesion is lower. It is also of interest to note that children with ventricular dilatation are grouped separately (Costello et al., 1988; Fawer & Calame, 1991). As mentioned in Chapter 1, it is thought that this dilatation can occur either following a haemorrhagic or ischaemic lesion.

From cerebral paly to 'clumsiness'

Without exception, studies report that CP is more commonly found among preterm children with a brain lesion than among those without a lesion. Moreover, the more extensive the lesion (e.g. haemorrhage into the parenchyma, cystic periventricular leukomalacia), the higher the probability of the presence of a neurological impairment. In addition, Cooke (1987) found evidence which suggests that the incidence of CP following bilateral lesions (irrespective of the type) is higher than after unilateral lesions. Furthermore, Fawer and Calame (1991) suggest that the anatomical site of cystic periventricular leukomalacia is related to type of deficit. Those with lesions in the frontal–parietal areas had either a hemiplegia or diplegia, while others whose lesion also extended into the occipital area developed quadriplegia.

However, children with less extensive brain lesions may also develop CP. Some children with isolated germinal matrix haemorrhages, intraventricular haemorrhages or ventricular dilatation (Cooke, 1987; Fawer & Calame, 1991; Ford et al., 1989; Levene et al., 1992; Van de Bor et al., 1993) have been found to show neurological abnormalities at school age consistent with signs of CP. Classifications range from a mild hemiplegia and diplegia to quadriplegia.

From the data gathered by the studies, it appears that not only was CP more common among children with lesions but that those children who did not develop CP were less competent in performing motor tasks at school age than their peers with a consistently normal scan (Costello et al., 1988; Sostek, in press). While these findings are common, not all studies show statistically significant differences between the groups. For example, Levene et al. (1992) and Marlow et al. (1989) report that the range of total impairment scores on the TOMI for children with a minor haemorrhagic or ischaemic lesion and those with a normal scan were similar. Marlow et al., however, express doubts about their own

findings. They question whether the technique used to identify lesions and their expertise in detecting minor ultrasound abnormalities was adequate at the time of the study. "It is, therefore, as yet not clear whether children with no cerebral palsy but poor motor skills have suffered similar but less severe brain injuries than those children with cerebral palsy." (p. 846).

Of the 2 studies which administered the Developmental Test of Visual–Motor Integration (Ford et al., 1989; Sostek, in press), neither found a significant difference between the performance of children with or without lesions on this test. However, Sostek (in press) found that children with haemorrhagic lesions had visual perceptual problems which might have contributed to their difficulties with tasks such as shape copying. Because only children with haemorrhagic lesions were enroled in these studies and there is no information on children with other types of lesions on this aspect of perceptuo–motor performance.

As noted above, a different paper–and–pencil task was given to the premature children in Costello et al.'s (1988) study. The children were tested on accuracy of drawing in a tracing task with various levels of difficulty. All children (including the controls) made more errors on the most difficult level. However, those with hydrocephalus/cerebral atrophy had the greatest difficulty. An interesting, but perhaps not surprising, observation was that the number of refusals to complete the task was also the highest for this group. This number increased with the increasing level of difficulty of the task (especially when asked to draw with the non–preferred hand). The authors concluded that because more children in this group were experiencing movement difficulties they were not only poorer on the task but also more reluctant to attempt the more difficult level.

Associated problems

Cognitive functioning

Some studies report an association between the extent or type of the lesion and cognitive ability while others do not. For example, Sostek (in press) found children who survived extensive haemorrhagic lesions to have a significantly lower mean IQ than children with minor Grades of haemorrhage. A similar trend was found by Cooke (1987) and Ford et

al. (1989). In contrast, Van de Bor et al. (1993) did not find a relation between extent of haemorrhage and cognitive ability. Furthermore, whereas Fawer and Calame (1991) found children with minor ischaemic lesions to show a tendency to be of slightly lower cognitive ability than those with isolated haemorrhages, the data of Levene et al. (1992) do not seem to support this advantage in cognitive ability of children with minor haemorrhagic lesions over those with minor ischaemic lesions.

Behaviour

Although none of the studies provide statistical evidence which would support the hypothesis that a brain lesion early in life leads to an increased risk of behavioural problems at school age, some report a trend towards a higher prevalence of problems among children with extensive haemorrhagic or ischaemic lesions. For example, the paediatrician involved in the study by Costello et al. (1988) judged both the children with ventricular dilatation and the combined group of hydrocephalus/cerebral atrophy as having more problems than their peers with isolated haemorrhages but the parents of the children did not agree with this observation. When more specific observations of behaviour were examined, Fawer and Calame (1991) found a (non-significant) higher prevalence of especially attentional problems among children with small focal PVL changes. On the other hand, the attention and distractibility ratings in Sostek's (in press) study failed to differentiate between children with minor and major Grades of haemorrhage.

2.3 Summary

Interest in the long term outcome of prematurely born children has steadily increased over the last 70 years. Early retrospective studies relying on clinical impressions have been replaced by prospective studies which use better testing procedures as well as more sophisticated statistical approaches to study the relationships between adverse events in the neonatal period and developmental status later in life.

Since the introduction of ultrasound, many centres have started prospective studies which are designed to examine the association between early lesions and functional outcome. At present, however, only the 9 studies described in this review have followed children for more than three years. Although there are differences between the studies in the maturity

of the children at birth, the equipment used to detect lesions, the classification of ultrasound abnormalities, age at follow up and whether or not a control group was included it is possible to extract some common findings with regard to the two central questions of this Chapter.

First, premature children with consistently normal ultrasound scans in the neonatal period are at a relatively low risk for developing major neurological impairments at school age. However, without exception all 9 studies have shown that many of these children lack adequate perceptuo-motor competence when compared to fullterm peers. Thus, despite being within normal limits on cognitive tasks, these children have perceptuo-motor difficulties which are observable in their every day life functioning.

Secondly, the presence of a brain lesion acquired in the neonatal period increases the probability of major neurological impairments. Perhaps not surprisingly this probability increases with the extent (or severity) and type of the lesion. For example, children with haemorrhagic lesions which extend into the parenchyma seem to be at a higher risk for later abnormalities than those whose lesion is restricted to the germinal matrix. Children with major ischaemic lesions such as cystic periventricular and subcortical leukomalacia are at the highest risk for later neurological deficits compared to both children with minor ischaemic (i.e. prolonged flares) and minor haemorrhagic lesions.

The most interesting finding from the point of view of the present study is that these most recent follow up studies echo the observation made at the beginning of this century that many premature children show subtle movement difficulties. However, one of our major criticisms of some studies is that this observation is mostly based on performance on a limited number of assessments. Another look at Table 2.2 shows that some studies administered just one general assessment. For example, in the study of Cooke (1987) follow up consisted of a(n unspecified) neurological examination and general physical examination. In contrast, Costello et al. (1988) elected to assess the children on a more diverse range assessments such as a detailed clinical and neurological examination (Amiel-Tison et al., 1983; Amiel-Tison & Grenier, 1986), items from Bax and Whitmore's (1973) motor assessment, items from the Developmental Test of Visual

Perception (Frostig et al., 1961), and items from the Merrill–Palmer Test (Stutsman, 1931). However, in general, follow up studies lack a series of assessments administered to the same children. As such, little is known today about the nature of the perceptuo–motor difficulties experienced by the children. It is to this issue we turn in the next Chapter.

CHAPTER 3

A closer look at perceptuo-motor problems in children

3.1 Introduction

As discussed in the previous Chapter, many studies have demonstrated a high prevalence of perceptuo-motor impairment among prematurely born children. However, the data these studies have provided are limited. Very rarely do they discuss what is understood by impairments of perceptuo-motor control or how the content of the assessments used influences the emerging picture of perceptuo-motor impairment. Similarly, the possibility that the children do not fall into one homogeneous category is rarely considered.

The present Chapter begins with a brief outline of the processes thought to be involved in the control of perceptuo-motor actions. This is then followed by a discussion of how children with impaired perceptuo-motor control are defined, the way their problems are assessed and the current evidence for the existence of sub-groups sharing similar profiles of performance.

Most of the studies mentioned in this Chapter do not stem from the literature on children born 'at risk' but rather have been concerned with describing the characteristics of 'clumsy' children in general. The majority of these studies started with children of school age identified as having difficulty in performing and/or acquiring perceptuo-motor skills. Subjects in such studies are not selected because they were born prematurely but retrospective inspection of their medical histories often indicate that many had difficulties in the neonatal period comparable to those experienced by the children in the present cohort.

3.2 Perceptuo-motor control: from neuron to action

Most movements are the result of an extremely complex interaction between the 'messages' to the muscles to move, and sensory information before, during and after the movement from our body and the external environment. The functional unit or building block which is fundamental to all motor behaviour is the neuron. These cells, unlike other cells in the body, can communicate with each other, often over great distances. "It is the properties of neurons, and the way in which they communicate with each other that underlie any movement, be it a simple reflex such as the knee jerk, or a detailed voluntary motor skill." (Greer, 1984; p. 18). However, movement arises against a background of

incoming information from the environment in which it takes place. It is, therefore, not possible to understand movement if perception is not considered too. Hence, perceptuo-motor is a term most often used to describe the area covered by research in human performance. Although perception and movement are inextricably intertwined, in what follows a rather simplified account of the contribution of each component to perceptuo-motor control and the consequences of impairments in any of these for the developing child will be discussed.

The 'perceptual' side of perceptuo-motor control

In order to be able to perceive, humans need to be able to collect information from the environment, a process which is referred to as sensory functioning. Perceptual functioning is then the process of attaching meaning to the sensory input. As such, there are six modes in which information about the environment can be available to us: visual, auditory, tactile, olfactory, gustatory, or proprioceptive. Of these six sources of information, vision is regarded as the principal and most comprehensive means of specifying the environment for movement.

Vision/Visual perception

Visual-perceptual development involves the child locating and knowing specific objects and their spatial and temporal relationships. The child needs to perceive objects as either parts or wholes and be able to combine them into larger configurations and patterns. Finally, children need to perceive distance, depth and to be able to detect and track movement (Keogh & Sugden, 1985).

In the most extreme case, loss of vision (congenital or acquired blindness) restrains perceptuo-motor development because it limits ways of knowing and organizing spatial information. This leaves audition as the only means of obtaining information about the spatial environment beyond the child's reach (i.e. when the child can not make use of tactile/kinaesthetic information). However, the egocentric spatial perspective of blind children is not necessarily limiting the development of manual skills as these are usually performed in near space (Sugden & Keogh, 1990). Even less serious visual disorders such as amblyopia which is defined as temporary or permanent subnormal visual acuity (Spreen

et al., 1984) may, if not corrected by glasses, affect the sighted child's perceptuo-motor development by means of distorting visual perception of form, colour, contour, size or movement. Similarly, strabismus (squinting) has been found by some (Abercrombie et al., 1964) but not others (Haskell, 1972) to affect performance on visual perceptual tasks which, in turn, may be associated with poor perceptuo-motor competence. Even when no visual defects are present, visual processes which go beyond simply detecting and actively scanning a stimulus in order to identify and analyze visual cues, i.e. visual information processing abilities such as being able to evaluate the correctness of a visual percept may be impaired in the developing child. These disorders are thought to be related to dysfunction of higher cortical centres (Bruce & Green, 1990) and may be revealed by administering assessments of spatial orientation, visual discrimination, object recognition, etc.. Impaired visual processing may contribute to poor perceptuo-motor control as seen in, for example, the case of a child sorting blocks of various sizes and shapes and then building a house with these blocks.

Recently, a series of studies have been conducted with the aim of investigating visual processing deficits among children with perceptuo-motor problems (Hulme et al., 1982; 1984; Lord & Hulme, 1988). It was concluded that for many children their 'clumsiness' stemmed from a difficulty in processing visual information (e.g. size constancy). However, because the conclusions of these studies were based solely on correlations, they have been criticised for suggesting a causal link between visual processing deficits and impaired perceptuo-motor functioning (Henderson et al., in preparation).

Proprioception

Proprioception or kinaesthesis refers to information about the movement of the body and its position in space available from receptors in muscles, joints, tendons, skin, and the balance organs in the vestibule of the inner ear [1]. Experimental data has revealed that if sensory information is artificially prevented from reaching the spinal cord when moving a limb (i.e. deafferentiation surgery), animals and humans can perform many responses

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[1] *In addition, vision has been shown to play a role in the control of posture and balance. Gibson (1966) termed this source of feedback 'visual proprioception'.*

nearly normally, although some decrements occur in most skills and serious decrements develop in skills requiring fine control of the fingers (Schmidt, 1982). Kinaesthesis is generally measured as the ability to detect differences or match quantities such as location, distance, weight, etc. in active, passive or constrained movements (Keogh & Sugden, 1985). Little is known at the moment about the development of kinaesthetic acuity and memory (in persons with no evidence of damage to the afferent pathways), but it seems that by the age of 8 years the level of kinaesthetic acuity in both active and passive movements has reached adult levels (Laszlo & Bairstow, 1980; Bairstow & Laszlo, 1981). Theoretically, non-optimal use of the feedback generated by limb displacement could influence the quality of subsequent movement (for example, under- or over- estimating the force needed to lift an object).

In contrast to the earlier mentioned studies which placed an emphasis on the association between impaired visual processing and perceptuo-motor problems, other studies have argued with equal conviction that difficulties in processing kinaesthetic information are largely responsible for impaired perceptuo-motor performance (Laszlo & Bairstow, 1985; Laszlo et al., 1988) (e.g. impaired ability of judging limb position). However, the results of Laszlo et al.'s studies on the association between kinaesthesis and motor control in 'clumsy' children have not been unequivocal, and several studies have failed to replicate their findings (e.g. Sugden & Wann, 1987; Hoare & Larkin, 1991).

In summary, problems in the processing of visual and/or kinaesthetic information often co-occur with poor performance on perceptuo-motor tasks. However, no firm evidence exists yet of a causal link between these perceptual deficits and impaired perceptuo-motor control.

The 'motor' side of perceptual-motor control

Changes in posture and limb orientation are achieved by the contraction of skeletal muscles. Precise joint movements require that activity in both agonist and antagonist muscles is regulated accurately and co-activation may be used to achieve better movement control (e.g. timing and sequencing). Also, different actions require different levels of muscle tension (e.g. force control).

At various levels of the central nervous system there are different networks of neurons each contributing to muscle control. Anatomically, the cerebral cortex is at the highest level and the spinal cord at the lowest level. Situated in between are a variety of structures including the cerebellum, basal ganglia and the thalamus. Both within and between these levels are feedback (and feedforward) reflex loops varying in latency which provide interactions between the components. For example, the monosynaptic stretch reflex is a short loop reflex (approximately 30 milliseconds latency time) that can provide automatic compensation for unexpected changes in the load acting on a muscle. This is experienced when the patellar tendon is struck lightly just below the kneecap when the knee is flexed (Schmidt, 1982). Movement, therefore, results from the cooperation among the system components which ultimately converge on the lower motoneurons connecting each muscle with the spinal cord (Greer, 1984).

In the case of children with spastic cerebral palsy it has been found that they may show a reversed order of distal and proximal muscle activation when adjusting postural control (e.g. Levitt, 1982; Nashner et al., 1983). Sugden and Keogh (1990) have suggested that the often observed hypertonicity during movement could be a compensatory means of stabilizing proximal segments during this inappropriate sequence of muscle contractions. A breakdown in the mechanisms which regulate the temporal sequence of activation may, in turn, produce different and less accurate kinaesthetic information (Shumway-Cook & Woollacott, 1985). Also, continuous contraction of the muscles in the child with spastic cerebral palsy could lead to secondary postural deformity which exacerbates impaired movement control by imposing biomechanical constraints. Similarly, slight postural abnormalities (e.g. scoliosis or inward turned feet) in otherwise 'normal' children may influence quality of performance (although not necessarily the ability to carry out perceptuo-motor tasks).

Whereas examination of the child with a central motor deficit reveals major (or 'hard') neurological signs of abnormalities in reflexes, tone or posture, it has been demonstrated that 'clumsy' children often exhibit minor (or 'soft') signs of neurological dysfunction (e.g. Forsstrom & Von Hofsten, 1982; Losse et al., 1991). Examples of minor neurological signs include such phenomena as associated movements (observed in the contralateral

limb or face), choreiform (jerky, irregular) movements, or postural asymmetries. Initially, assessments which included items designed to elicit minor neurological signs were criticised because of the presumed unreliability of these signs. However, it has now been shown that many measurements of 'soft' signs are in fact quite reliable (Shafer et al., 1983). Today the origin of minor neurological signs is still not well understood and neither do we know yet whether they are in any way **causally** related to impaired perceptuo-motor control. Lunsing et al. (1992) have argued that "Their significance is that the nervous system of these children is wired differently from that of normal children. This might imply an increased vulnerability of the brain to exogenous influences, e.g. interval diseases, rearing attitudes and psychosocial circumstances. As a result, behavioural and cognitive problems may occur." (p. 402).

The relationship between the presence of minor neurological signs and motor control among 'clumsy' children was recently studied by Lundy-Ekman et al. (1991). They found that 'clumsy' children who showed minor neurological abnormalities believed to be associated with cerebellar dysfunction, i.e. dysmetria, dysdiadokinesis and intention tremor [2], were extremely variable in their response on tapping tasks. In contrast, 'clumsy' children who showed minor neurological abnormalities thought to be associated with dysfunction of the basal ganglia, i.e. choreiform movements, athetotiform movements and synkinesis [3], were unimpaired on the tapping task but were more variable in controlling the output of isometric force impulses to match a target. The results on the tapping tasks (i.e. timing of movements) were later replicated in a study by Williams et al. (1992). These studies suggest, therefore, that the control of time and force are separate components of coordination, that their computations are dependent on different neural structures and that minor abnormalities in structures such as the cerebellum and basal ganglia may play a central role in the variability of output which characterises the performance of many 'clumsy' children.

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[2] *dysmetria=inability to produce the correct distance for movements; dysdiadokinesis=inability to perform rapid, alternating movements; intention tremor=low frequency oscillation during intended movements.*

[3] *Choreiform movements=jerky, irregular movements; athetotiform movements=small, slow, writhing movements; synkinesis=type specific activation of heterologous muscles.*

In summary, impairment in the regulation of timing, sequencing or force aspects of muscle activity and may lead to impaired perceptuo-motor control. The presence of minor neurological signs are probably indicators of a 'noisy' perceptual-motor system and may interfere with a child's ability to perform tasks at an appropriate level.

Movement, action and competence

Most of the movements we make in daily life are goal-directed, i.e. they involve an action. To describe my own movements at this moment I would not say "I am moving my fingers towards the different keys on the key-board and press each in a sequence, while contracting my muscles in a certain order", but rather I would say "I am typing". Action differs from movement in some of the same ways that perception differs from sensation. That is, when we think of an action, defined in terms of a goal, we do not think of the particular movements by which it is mediated. The use of the term action implies a higher-level description of what we do (Smyth & Wing, 1984). The same act can be carried out by different movements, depending on the circumstances (I could use my toes instead of my fingers to type if I want to hold my cup of tea at the same time).

Competence could then be defined as having the necessary ability to carry out an action. For example, I have to be able to see the keyboard in order to direct my fingers to the different keys, I need enough muscle power to press the keys (although gravity helps me here), and I have to know how to spell the words (in English!) in order to type this thesis.

It is now recognized that perceptuo-motor competence can determine the extent to which a child can function effectively within the school environment (Henderson & Sugden, 1992). Any impairments in the 'perceptual' and 'motor' processes described above may, hypothetically, interfere with a primary school child's competence in handling scissors or playing ball games. The learning of new skills such as writing or, later in secondary school, handling laboratory equipment during science lessons may also be hampered.

3.3 Children with impaired perceptuo-motor control - a continuum?

The severity of the problems observed among children with impaired perceptuo-motor control varies widely and, therefore, classification has proved a difficult exercise. Over

the years there have been many 'visions and revisions' in the way professionals classify children with perceptuo-motor problems (Henderson & Sugden, 1992). Whereas some have argued that children with cerebral palsy and those with mild to moderate perceptuo-motor problems are just two extremes of the entire spectrum of children with perceptuo-motor problems (Dare & Gordon, 1970; Gubbay, 1975), others take the view that children who have obvious difficulty in performing and/or acquiring perceptuo-motor tasks but who do not show major signs of neurological dysfunction upon a standard neurological examination constitute a separate group (e.g. DSM-III-R, 1987).

In discussing the problem of defining cerebral palsy, representing the severe end of the continuum of perceptuo-motor problems, Alberman (1984) stressed that a definition of a developmental disorder should embrace the following three criteria: repeatability, sensitivity and specificity. Repeatability refers to the desirability of all observations made on a single child being repeatable by the same and different observers at all times. Sensitivity is the ability to classify a genuine case correctly, and specificity is the ability to classify correctly those who are not genuine cases. Though few people would disagree with the importance of these criteria they prove more easily formulated than applied in real life. This is the case whether one is concerned with children with cerebral palsy or children whose perceptuo-motor problems do not seem to stem from an identifiable neurological impairment.

Cerebral palsy

Cerebral palsy is generally defined as a "..non-progressive disorder of movement and posture due to a defect or lesion of the immature brain" (Bax, 1964) and is considered to be a persistent rather than transient condition (Ingram, 1964). However, "Cerebral palsy is not a disease but a symptom complex, akin to the terms mental deficiency or epilepsy." (Hagberg & Hagberg, 1993; p. 67). Although the term cerebral palsy seems useful in society (e.g. the uniting effect on families with common problems) and for the provision of services, it is now clear that the biological condition is heterogeneous. Moreover, it has been argued that because the central nervous system develops so rapidly during the early years, movement problem manifestations change with age, which makes diagnosis difficult and seemingly unstable over a period of years (Blair & Stanley, 1985).

Recently, a Working Party was set up in the United Kingdom (under the auspices of the Medical Education and Information Unit of the Spastics Society) to review the way clinicians describe motor deficits classed under the umbrella term of 'cerebral palsy' (Evans & Alberman, 1985; Evans et al., 1986; 1989). One of the conclusions of this group was that terms such as diplegia, hemiplegia and quadriplegia continue to be useful in clinical discussion but are of limited value for epidemiological studies because different clinicians use these terms to mean different things. It was agreed that a new terminology would be adopted and that rather of speaking of cerebral palsy a new term **central motor deficit** (i.e. a motor deficit arising from a lesion of central origin) should be introduced. In addition, the participants set out to devise an epidemiological tool which would facilitate the standardised recording of the motor deficits and associated sensory and intellectual deficits in children. For example, it was agreed upon that the definition of spasticity should be a: clasp-knife increase in muscle tone identified on passive movement (and often with increased tendon reflexes) (Evans et al., 1986; p. 547). Nevertheless, epidemiological studies which have since adopted this standardised way of recording central motor deficits are still reluctant to adopt this new terminology and continue to describe their population according to the 'traditional' classification of cerebral palsy (e.g. the POPS study in the Netherlands; Van de Bor et al., 1993).
In the present thesis this new terminology is adopted and the term 'cerebral palsy' is only used when referring to data from studies which used to describe their findings as such.

Children not classified as having a central motor deficit

Given the observation that manifestations of perceptuo-motor problems change in the first years of life (Blair & Stanley, 1985), and that many cases of children with a central motor deficit are not diagnosed until the children are between 3 and 5 years (Evans et al., 1986) this means that at the 'mild' end of the spectrum there may well be cases in which it is difficult to decide (even when 'hard' evidence on the presence of brain abnormalities is available) whether or not to classify a child as suffering from a central motor deficit. As Denckla and Roeltgen (1992) comment: "..the presence of subtle but traditional neurological signs does not universally trigger a diagnosis of 'cerebral palsy'." (p. 456). They conclude, therefore, that "This issue regarding the line between cerebral palsy and clumsiness is the least well established topic herein discussed." (p. 456).

Even though an increasing effort has been made since, for example, Orton (1937) drew the attention of medical and educational professionals to the existence of children who have difficulty in performing and/or acquiring perceptuo-motor skills, the concept of 'clumsiness' remains as contentious as 'cerebral palsy'. As with many developmental disorders it is difficult to provide a clear definition of 'clumsiness' or perceptuo-motor problems. As far as we are aware, none of the definitions which have been put forward so far have actually been tested in relation to any of the three criteria outlined by Alberman (1984) and attempts to define the characteristics of this group of children vary according to the perspectives and bias of the researcher.

When in the mid 1960's the first case studies and systematic empirical work began to appear in the literature (e.g. Walton et al., 1962) the term 'clumsy child' was introduced and despite its negative connotation is still the most widely used today. However, a number of other terms have appeared in the literature such as 'developmental dyspraxia' (Denckla, 1984), 'Developmental Coordination Disorder' (DSM III-R, 1987) or 'Specific Motor Retardation' (ICD-9-CM, 1989). As will be discussed in the next paragraphs, some of these terms are now used to represent different categories of children with perceptuo-motor problems.

Gubbay's (1975) definition is one of the most widely quoted. He defined the child with perceptuo-motor problems as "..one whose normal ability to perform skilled movement is impaired, despite normal intelligence and normal findings on conventional neurological examination" (p. 39). Similarly, Wall (1982) defined 'physically awkward' children as "..children without known neuromuscular problems who fail to perform culturally-normative motor skills with acceptable proficiency" (p. 254). Since then, definitions have broadened to include a wider variety of children. For example, Henderson and Hall (1982) who also used the term 'clumsiness' to describe these children state that: "Generally the term is used to describe children whose level of competence in motor skills is significantly below the norm, but who show no evidence of disease of the nervous system .... More often detailed analysis reveals a wide range of disorders and dysfunctions, with poor motor coordination being but one component" (p. 448). Recently a definition has been provided by the American Psychiatric Association (APA) in the Diagnostic and

Statistical Manual of Mental Disorders (DSM III-R, 1987) which says: ".. the essential feature of this disorder is marked impairment in the development of motor coordination that is not explainable by mental retardation and is not due to a known physical disorder" (entry 315.40, p. 48). The label used in this Manual is Developmental Coordination Disorder (DCD).

Recently, it has been argued that among children with mild to moderate perceptuo-motor problems there are those whose main difficulty lies in the *execution* of movements and those whose most prominent characteristic seems to be an impairment in the *planning* of movements. An example of this sub-division can be found in the category of 'Special Motor Retardation' put forward by the ICD-9-CM (1989). Currently the ICD-9 definition of Special Motor Retardation is "Coordination disorder (clumsiness syndrome, dyspraxia syndrome, specific motor developmental disorder).." and described as "..disorders in which the main feature is a serious impairment in the development of motor coordination, which is not explicable in terms of general intellectual retardation; the clumsiness is commonly associated with perceptual difficulties". In particular, developmental dyspraxia has defined by Deuel (1992) as: ".. the inability to learn and perform age-appropriate sequences of voluntary movements in the face of preserved coordination, strength, and sensation" (p. 64). As such, motor performance is only part of the problem in the dyspraxic child and motor learning is severely compromised. When occurring in isolation the child shows age-appropriate fine motor skills but fails to learn age-appropriate motor sequences (Deuel, 1992). It is thought that these problems result from a failure at the higher cortical, conceptual-organisational level of motor control (Miller, 1986).

Ever since the term dyspraxia appeared in the literature, however, there has been much debate over its use. Three examples are given here. Denckla (1984) caused some confusion with the title of her paper 'Developmental dyspraxia: The clumsy child' (1984), suggesting that the words 'clumsiness' and 'dyspraxia' were synonyms and could be used interchangeably. However, recently Sugden and Keogh (1990) have emphasised the differences between 'developmental dyspraxia' and 'clumsiness' again and agree that ".. dyspraxia is a planning problem and clumsiness is poor performance quality.." (p. 154). A final example in the confusion over the definition and delineation of the term dyspraxia

comes from Denckla and Roeltgen (1992). They have argued that, following the traditional neurological classification, the term dyspraxia should actually only be reserved for those children who have all perceptuo-motor abilities necessary for the proper execution of the required movement but who have difficulty with performing *representational and non-representational gestures*. Not only has the use of the term developmental dyspraxia in their eyes been applied improperly to describe children who have perceptuo-motor impairment but, moreover, they preserve this term purely for impairments of gestural movements.

From these examples it would suffice to say here that the foundations on which a classification system which makes a distinction between 'clumsiness' and 'dyspraxia' rests are still speculative and remain relatively arbitrarily. Moreover, it seems probable that 'clumsiness' and 'dyspraxia' may both be observed in the same child (David et al., 1981). It will not be until studies are conducted which closely scrutinise the characteristics of individual children with perceptuo-motor problems that the reliability and validity of this distinction can be established.

In this thesis the view is taken that children with perceptuo-motor problems are those who have difficulty performing tasks with varying degrees of perceptual and/or motor demands to such a degree that their performance is significantly poorer than that of their age-matched peers. Children classified as having a central motor deficit by the paediatrician in the present study on the basis of observations made during the neurological Examination are excluded from this category.

3.4 Aetiology

Because the present thesis is concerned with prematurely born children, one might ask the question of how relevant the data on children identified at school age as having perceptuo-motor problems are in this respect. Of those studies which have retrospectively examined the array of possible aetiological factors related to perceptuo-motor problems later in life, there are some who found a clear indication of a higher prevalence of perinatal and neonatal complications and others report that these children do not differ from their non-affected peers in the events surrounding birth (e.g. Schoemaker, 1992).

Among those studies which did find a more eventful history among children with perceptuo-motor problems, prematurity and low birthweight are often mentioned. For example, Gubbay (1978) found that in a group of 39 children, 33% had abnormalities of pregnancy, 14% had abnormalities of labour and 17% suffered from abnormalities of delivery. In addition, 10% of children were of low birthweight and 23% experienced neonatal problems. Johnston et al. (1987) described a greater prevalence of perinatal complications, low birthweight and a higher prevalence of prematurity. Henderson and Hall (1982), Stephenson et al. (1991) and Hoare (1991) reported a preponderance of difficulties in labour, complications during pregnancy, prematurity and neonatal problems among children with perceptuo-motor problems. It seems, therefore, that there is an overlap in neonatal history between 'clumsy' children identified at school age and prematurely born children.

Other aetiological factors which have been suggested to be associated with the difficulty of performing and/or acquiring of perceptuo-motor skills include heredity and genetic factors (Gordon & McKinlay, 1980), learning experience (i.e. restricted opportunity) and emotional state (Barnett, 1992). These same factors have to be considered when studying prematurely born children.

In sum, speculations about causes of perceptuo-motor problems are many and varied. Clearly, a multifactorial aetiology has to be considered including both physical and environmental influences. The results of the present study could shed more light on the association between one potential aetiological factor among prematurely born children, i.e. the presence of brain lesions in the neonatal period, and perceptuo-motor problems later in life.

3.5 Issues in the identification and assessment of perceptuo-motor problems

Variability in perceptuo-motor development is normal within children of a given age range: not every child can walk unassisted at 12 months or handle a cup well at 21 months of age, nor is every 6-year-old able to catch a ball. Children develop skill at different ages, often in a different order and to a different extent. This makes judgements as to whether or not a child has a perceptuo-motor problem more complicated.

The developmental profiles of children with mild to moderate perceptuo-motor problems are extremely varied. Sometimes in the first years of life their development could be described as normal and it is only when the child enters school that the problems are recognised as from this age the demand on motor skill increases, particularly in writing and physical education. At other times, however, differences with other children can be noted much earlier. Stephenson et al. (1991) documented the various routes by which 31 'clumsy' children ended up being referred to occupational therapists. General practitioners, teachers and parents all played a crucial role in determining the course of the diagnostic pathway, while educational psychologists initiated most referrals to occupational therapists. From interviews with the parents it became apparent that nearly half believed that a problem existed before the child's fourth birthday. Nevertheless, these suspicions were hardly ever acted upon immediately. It is interesting to note that in half of the cases where parents had suspected difficulties and sought further examination, the child had been treated at a Neonatal Intensive Care Unit shortly after birth. However, "Reasons were varied and not restricted to low birthweight and, in one case, it was related to the specific condition of the mother" (p. 104). On the other hand, half of the parents reported that they had had no anxieties regarding the child's development until primary school education started and teachers began to express their concerns. At this age, school medical examinations seem a particularly good opportunity to identify those children with perceptuo-motor problems (Bax & Whitmore, 1987; Schoemaker, 1992).

Assessment instruments

The content of assessment instruments used to identify children with perceptuo-motor problems is varied and reflects the complexity which underlies the spectrum of problems to be found in individual children. At one end of the spectrum, there are assessments which include a variety of items, designed to tap a range of different facets of performance. For the neurologist the presence or absence of (minor) neurological abnormalities is of interest and assessments may include abnormalities of posture, reflexes, associated movements, etc. in addition to fine manipulative abilities or gross motor skills (as for example in the Examination of the Child with Minor Neurological Dysfunction; Touwen, 1979). In contrast, global assessments of perceptuo-motor ability used by psychologists tend not to involve the testing of reflexes or posture but focus only on a

range of fine and gross motor skills (e.g. the Movement Assessment Battery for Children; Henderson & Sugden, 1992). At the other end of the spectrum, assessments designed to measure highly specific aspects of functioning such as copying geometric shapes (e.g. Beery, 1982) have been frequently administered.
Ideally, a mixture of these two types of assessment should be included in any follow-up study. Furthermore, they should be administered to all children included in the study, be it those with known central motor deficits, perceptuo-motor problems or 'normal' children as intra-individual variability of abilities can be found and careful evaluation of performance can lead to more precise and accurate descriptions of behaviour.

Having said the above, the answer to the question as to how and what to assess remains still far from clear (Denckla & Roeltgen, 1992). Keogh et al. (1979) have shown that the use of different measures (classroom teachers, physical education teachers and a movement skills test) leads to the selection of different subjects from the same population. Similarly, Maeland (1992) found that although two individually administered standardised assessments of motor competence and a teacher questionnaire identified roughly the same number of children with perceptuo-motor problems among a cohort of 10-year-olds, each measure identified a somewhat different group. Therefore, depending on the method of assessment used the characteristics of the groups of children used in studies will vary.

Also, there are no clear criteria for deciding whether a child has problems. For example, both Van der Meulen et al. (1991) and Geuze and Kalverboer (1987) used the Test Of Motor Impairment (Stott et al., 1984) to select children with perceptuo-motor problems for a series of experimental studies. Whereas Van der Meulen et al. chose to select children whose scores on the TOMI fell in the bottom 20th centile, Geuze and Kalverboer decided to be more stringent and only selected those children whose scores fell in the bottom 10th centile. Consequently, prevalence figures of children described as having perceptuo-motor problems vary according to the assessment procedure and cut-off criteria used. In general, the percentage of children considered to exhibit definite perceptuo-motor problems in the general population of school children is reported to be between 3 and 10 % (Schoemaker, 1992). However, at present there are no proper epidemiological studies which documented the incidence or prevalence of children whose sole difficulties lie in

the perceptuo-motor domain (Denckla & Roeltgen, 1992). The number of boys affected is usually found to be higher than the number of girls although not invariably (Gubbay, 1975).

3.6 Sub-groups of children with perceptuo-motor problems

Ever since children with perceptuo-motor problems have been studied attempts have been made to search for sub-groups. Broadly speaking two approaches have been taken to identify sub-groups: 1) the **clinical/ descriptive** and 2) the **statistical** approach. Within both approaches two further sub-division can be identified: a) investigating performance across several domains of which perceptuo-motor ability is just one (in addition to, for example, cognitive ability, language, etc.) or, b) investigating the differentiation of ability specifically within the perceptuo-motor domain (e.g. fine and gross motor skills). In what follows examples of both approaches will be discussed.

1) Clinical/descriptive approach

When observing children who are struggling with a given perceptuo-motor task it is obvious from qualitative observation that the reasons for failure can be diverse. Several studies have demonstrated a variety of profiles among children described as 'clumsy'. For example, Gubbay et al. (1965) came to the conclusion that a group of 21 children whom they examined could be divided into two sub-groups. The first group consisted of children with developmental apraxia and/or agnosia in isolation. The second group identified by Gubbay et al. consisted of children whose difficulties were thought to be primarily due to similar executive or cognitive deficits, but in whom a minimal evidence of dysfunction in pyramidal or cerebellar pathways was found.

Similarly, De Ajuriaguerra and Stambak (1969) suggested that the children they studied fell into two roughly comparable categories. The first group did not show many signs of specific motor damage. There was usually no accompanying neurological problem but the body schema was disorganised and associated emotional problems were common. The second group were fairly homogeneous and appeared to suffer specifically from motor problems. There was no severe disorganisation of body schema, no emotional problems or deficits of visual gnosis, however, minor signs of neurological damage were often

present.

Henderson and Hall (1982) took a more holistic perspective in their description of children with perceptuo-motor problems as they also included other characteristics. As in the above described studies they were also able to distinguish between two distinct groups out of a group of 16 children with perceptuo-motor problems. One group consisted of children of above-average intelligence and in whom motor difficulties seemed to be an isolated problem. In another group, the perceptuo-motor difficulties were associated with numerous other difficulties. These children's cognitive abilities were at the lower end of the normal range, their general academic attainment was low and they were considered socially immature. The majority had speech problems and felt negative about school. Finally, there was a third group of children who could not be readily classified in either of the two groups.

Those researchers who preserve the term 'developmental dyspraxia' for children who have difficulties in planning movements as opposed to executing movements (see earlier) have tried to construct a taxonomy based on domain specific dyspraxias. For example, Miller (1986) roughly divided developmental dyspraxia into two categories. Following the adult literature on apraxia he, firstly, distinguishes children who have 'gestural dyspraxias'. These are children who have difficulty in imitating or spontaneously generating representational and non-representational gestures. As discussed previously in the section on definition he notes that: "For many, gestural dyspraxias are the only true dyspraxias, the others being seen as disturbances due to other reasons, such as dysfunction in other aspects involved in motor planning (for example, visual-perceptual), defects in different symbol systems (for example, linguistic), or in other motor systems (such as ocular-motor or extrapyramidal)." (p. 16). The second sub-group of developmental dyspraxia are those children who have 'constructional dyspraxia'. This last category has recently received much attention. Deuel (1992) included this category among the 'material-specific dyspraxias'. According to her, this term ".. implies that motor execution becomes inefficient only when certain cognitive materials are utilized to direct the motor output." (p. 267). Constructional dyspraxia can be apparent in two main areas, namely, two-dimensional and three-dimensional construction. Two-dimensional constructional tasks

such as form boards, block and stick designs as well as a range of pen–and–pencil tasks such as drawing and copying geometric shapes, copied and spontaneous drawings, and writing often pose a difficulty for these children (Miller, 1986). Alternatively, three–dimensional construction can be impaired as assessed through tests of assembly of objects or copying 3–D block designs.

2) Statistical approach

In contrast to descriptive approaches the use of statistical procedures to quantitative identification of homogeneous groups within the pool of children with perceptuo–motor problems has received limited attention (Ayres et al., 1987; Hoare, 1991). This approach employs techniques such as factor and cluster analysis, the former being applied to detect underlying abilities which may represent patterns of dysfunction and the latter a technique designed to group subjects together on the basis of similar profiles across tasks.

One of the first steps towards the production of a taxonomy of perceptuo–motor skills in children was taken by a research group directed by Rarick (e.g. Rarick et al., 1976). These studies involved children of both normal cognitive ability and retarded cognitive ability. In order to arrive at clusters of relatively homogeneous groups of children on the basis of their movement ability, Rarick et al. first set out to examine how the movement tests themselves group or cluster. They selected 46 tests representing 12 hypothesised movement abilities: static muscular strength, explosive muscular strength, muscular strength–endurance, gross body coordination, cardiorespiratory endurance, limb–eye coordination, manual dexterity, static balance, dynamic balance, flexibility, body fat and body size. Following a series of factor analyses, it emerged that 6 common movement factors could be identified, regardless of sex and level of cognitive functioning. Two factors consisted of measures of physical size and body composition. The remaining factors represented a variety of perceptuo–motor skills clusters: gross limb–eye coordination (e.g. throwing a ball at a target), fine visual motor coordination (e.g. pegboard), balance (both static and dynamic), and leg power and coordination (e.g. running). Having established this factor structure, Rarick and colleagues then went on to examine the profiles of relatively homogeneous groups of children of normal cognitive ability. For example, the profile of one group showed that they were slightly below

average on the strength–power, gross limb–eye coordination, balance, and leg power–coordination factors, but these children had particularly low scores on the fine visual motor coordination tests.

The first comprehensive study on sub–typing among children with perceptuo–motor problems was conducted by Ayres and her colleagues (Ayres et al., 1987) who tried to determine whether sub–groups of developmental dyspraxia actually exist. Although clinical descriptions of different types of problems were given no conclusive evidence was found in support of sub–groups. However, using cluster analysis techniques Dewey and Kaplan (1992) were able to distinguish different patterns of performance among children with perceptuo–motor problems. They included: deficits mainly in balance; deficits in praxis, motor sequencing and coordination; severe deficits in all motor skill areas; and subtle motor deficits which were only evident when children were compared with matched controls. The authors interpreted their results as providing preliminary support for sub–groups of children with perceptuo–motor problems which differentiate between children who have difficulty planning motor activities (i.e. motor sequencing) and those who have difficulty in the execution of motor skills (i.e. balance, coordination).

The most detailed attempt at classifying perceptuo–motor problems so far was conducted by Hoare (1991). She set out to compare the performance of 6 to 9 year old children with perceptuo–motor problems and a control group across a broad range of tasks [4] . The 32 perceptuo–motor tasks included kinaesthetic, visual, cross–modal (kinaesthetic and visual), fine motor and gross motor tasks. Two of the questions addressed in her thesis focused on what types of perceptual and motor tasks would best discriminate between the two groups and whether sub–groups of perceptuo–motor problems could be identified among the affected children.

To address the first question, the 32 variables were subjected to a discriminant function analysis and it was found that 4 variables contributed significantly to the separation

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[4] *It was interesting to note that a significant higher proportion of children with perceptuo–motor problems were born prematurely than the control children (31% versus 13%).*

between the groups of children with or without perceptuo-motor problems: stationary hop on one foot (which was the singularly best predictor of 'clumsiness'), static balance on one leg with eyes open, run (50 metre sprint), and matching the length of lines in the cross-modal condition (i.e. matching kinaesthetic input with a visual display).
Following factor analyses on the 32 variables in the group of children with perceptuo-motor problems, 9 consistent factors were identified. The first factor which accounted for the largest proportion of variance could be described as 'manual dexterity'. Other main factors were described as representing gross body coordination, balance/hop, vision and active kinaesthesis abilities. In general, Hoare's findings supported the separation of perceptuo-motor tasks into fine and gross motor categories, with the gross motor category further subdivided into static/dynamic balance and general body coordination. Three of these factors were similar to those reported by Rarick et al. (1976; see earlier).

To address the final question on whether sub-groups of children with similar perceptuo-motor problems could be detected, Hoare applied a number of cluster analyses. The six variables which entered these analyses measured kinaesthetic acuity, visual perceptual functioning, visual-motor functioning, fine motor ability, static balance, and dynamic gross motor ability. Scores on the clusters were standardised around the group means of the children with perceptuo-motor problems (as opposed to around the group means of the control children). Five clusters emerged from the analyses. These results, therefore, supported the notion of heterogeneity within samples of children with perceptuo-motor problems with a number of distinct patterns of dysfunction emerging.

Limitations of clinical/descriptive and statistical approaches

In general, there are some limitations to the findings of the above clinical/descriptive and statistical approaches on sub-grouping. First, the methods used for identifying the children influences the characteristics of the sample. Therefore, the results are only applicable to the specific populations studied and replication of these findings are necessary to decide whether they can be generalised to other groups of children with similar problems. A second, more specific limitation in the case of statistical studies, concerns the process of establishing sub-groups. Although selection of variables which enter the analyses are well justified and logically follow on from previous findings, it should be kept in mind that

selection of different variables might have altered the outcome of the cluster analyses. However, in spite of these limitations a search for sub-groups using these techniques provides a starting point from which other experimental techniques might be used to test their validity. Also, these results may lead to the generation of hypotheses that are more theoretically based.

3.7 Summary

Since the turn of the century there has been a debate about the definition and classification of perceptuo-motor problems in children. This is true both for children currently described as suffering from a central motor deficit and those who are referred to as 'clumsy'. Moreover, the grounds on which such a division between severe and mild to moderate perceptuo-motor problems should be made are still not well defined. With respect to 'clumsiness' agreement seems to exist on two basic features, i.e. the absence of severe cognitive impairment and a known, recognisable neuromuscular disorder (e.g. central motor deficit or muscular dystrophy). Minor neurological abnormalities, poor academic achievement, emotional and behaviour problems are all possible but not invariable concomitants of perceptuo-motor problems, and are likely to interact with progress. Identification of the problems either take place early in life but more commonly occurs when the children have entered school and the demands placed upon them by the environment increase. Because perceptuo-motor functioning plays a central role to development in general, its disruption could affect widely different areas.

At present 'clumsiness' is still viewed by the majority of professionals as one all-inclusive entity. However, children show varying profiles of strengths and weaknesses across the whole spectrum of perceptual-motor abilities. Recently studies have attempted to divide these children into sub-groups both using a descriptive and statistical approach at either the level of underlying mechanisms or at the level of failure on individual tasks. Preliminary results have shown that it is possible to distinguish between specific sub-groups of children with perceptuo-motor problems.

CHAPTER 4

Aims of the study

In the previous Chapters, an attempt has been made to bring together a number of different bodies of literature relevant to the understanding of perceptuo-motor difficulties in prematurely born children. From these reviews it has become clear that further investigations are needed into these difficulties if we are to fully appreciate their impact on the children as they grow up. In this thesis an attempt will be made to address a number of questions which will each, at a different, level contribute to our understanding of perceptuo-motor competence in prematurely born children. The aims of the study and their justification will be dealt with under four headings.

Premature children at 6 years - a global view of perceptuo-motor competence

Our objective in the first empirical Chapter, Chapter 6, is to replicate earlier findings and to expand our knowledge of what is generally known about neurological and perceptuo-motor performance in prematurely born children. Although numerous longitudinal studies have documented the presence of perceptuo-motor problems in children born prematurely, these studies are limited in a number of ways. For example, in most cases the information provided on the range and severity of the children's problems tends to be based on a small number of assessments yielding composite scores. In this study we have used a series of 8 assessments containing a total of 60 items and provide data in various forms ranging from total scores that are comparable to those provided in other studies, to very detailed accounts of how the children performed particular tasks in the battery. In order to achieve our objective of replication and expansion, the battery includes a number of norm-referenced assessments that others have used as well as some entirely new and rather experimental measures designed especially for the study. Using the 4 norm-referenced measures in our battery we began by comparing our cohort of prematurely born children with randomly selected children whose perceptuo-motor competence is believed to represent the normal range. For completion, we also provide data on how these same children compared with their peers on measures of cognitive ability, behaviour and self-concept.

In previous studies every conceivable 'risk' factor has been investigated in relation to the cognitive development of children born prematurely. This stands in sharp contrast to the number of investigations pursuing the relationship between these factors and perceptuo-motor competence. Although in this study we have data available to investigate these relationships exhaustively, for this thesis we have elected to be rather selective and examined only a subset of all possible variables. From the neonatal period the two most commonly included variables gestational age and birthweight were selected. From the set of demographic variables we selected the variables gender, ethnic origin and mother's educational background.

As already noted, the classification of perceptuo-motor performance of children born prematurely ranges from a central motor deficit (or cerebral palsy) with which no clinician would disagree and extends through the difficult classification of 'clumsiness' to normal. While all scientists in this field acknowledge that it is unsatisfactory, what tends to happen in follow up studies is that children with a central motor deficit are described in a different way from other children who have less severe movement problems. Since there is no satisfactory solution to this problem at present, we have also adopted the strategy of dividing the children into two groups but have attempted to provide more data on performance of the children identified as having a central motor deficit than other workers. Also, we have made the group of children labelled 'clumsy' the major focus of our enquiry providing extensive data not only on their perceptuo-motor performance but also on other aspects of behaviour. In the final section of this Chapter, therefore, we discuss questions relating to how prevalence rates for perceptuo-motor problems changes according to the assessment used and examine patterns of associated problems that these children experience.

Neonatal brain lesions and perceptuo-motor competence at 6 years

Although nearly all previously reviewed studies compared premature children with lesions to those without, few investigated whether children with different types of lesions show different patterns of behaviour. One of the objectives of this study, therefore, was to undertake a detailed investigation in Chapter 7 of our cohort of prematurely born children categorised according to the type and severity of the lesions they had exhibited.

To achieve this we began by exploring the performance of the two most 'extreme' groups, namely children whose ultrasound scans had been classified as either consistently normal or as showing 'major' haemorrhagic and/or ischaemic lesions. Studies which included children with these latter types of lesions tend to describe their performance in summary form and, at best, provide a table which simply lists their physical and sensory impairments, sometimes supplemented with a general statement about their cognitive abilities. In the present study, we attempt to examine profiles of these children's performance in a way that might identify variations in the pattern of their impairments.

Having examined the outcome of the above two groups we then addressed four questions which focused on the neurological status and perceptuo-motor competence of children who were diagnosed in the neonatal period as suffering from what are now regarded 'minor' brain lesions [1].

As already discussed, studies have generally found a relation between the Grade of haemorrhage and outcome beyond 4 years of age. The more extensive the lesion, the poorer the prognosis. Although children with 'minor' Grades of haemorrhage (i.e. Grade I or II) have seldom been found to develop a central motor deficit, they either show subtle perceptuo-motor difficulties at school age or are indistinguishable in their performance from their premature peers who did not suffer from a brain lesion. Similarly, children with 'minor' ischaemic lesions (i.e. non-cystic PVL) classified as either 'flares' (Levene et al., 1992) or small focal PVL (Fawer & Calame, 1991), seem to do less well particularly on tests of perceptuo-motor competence. We will examine both groups of children with minor lesions in our cohort to see whether we can support these findings.

Careful examination of the evolution of lesions has shown that in some children a haemorrhagic lesion is seen in combination with echodensities in the periventricular area (flares). Compared to children with isolated 'minor' haemorrhages or flares without other

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[1] *Some of the studies referred to in this section have not been discussed before in this thesis because the cohort they studied had not yet reached school age. It was felt, however, necessary to include these here in order to provide a comprehensive background to the questions addressed.*

ultrasound abnormalities, it could be argued that those with a combined lesion are at an increased risk for later perceptuo-motor problems due to the additional damage sustained in other vulnerable and rapidly developing parts of the brain. Two studies have so far reported the long-term outcome of children with a combined lesion. First, Cioni et al. (1992) discussed the outcome of twelve children with a combination of a 'major' haemorrhage (large intraventricular) and prolonged flares. Five out of the 12 infants showed cerebral palsy (one tetraplegia, three diplegias and one hemiplegia) and one infant had a mild motor abnormality in one arm. The remaining six infants all had a normal development. Secondly, and more relevant for the specific question asked here, Levene et al. (1992) were able to follow ten children with a combination of a haemorrhage and flares which persisted for over 2 weeks ('prolonged' flares) until school age. One child (with a haemorrhage extending into the parenchyma) was diagnosed as having a right hemiplegia at 5 years of age. The other 9 children, who had either a germinal matrix or intraventricular haemorrhage, did not show signs of a central motor deficit but many were poorly coordinated for their age. As several children in our cohort were also found to have a combination of a haemorrhage and flares we investigated whether we could add some more specific data on the absence or presence of perceptuo-motor problems to these findings.

In the present study a number of children presented with dilated ventricles on the first ultrasound scan after birth. It was not possible to establish whether an earlier perinatal insult (and of what type) had taken place. To the best of our knowledge, no reports exist in the literature which have studied the long-term outcome of children with this particular abnormality. However, there are some reports which describe the long-term sequelae of children who, on sequential ultrasonography, were shown to gradually develop ventricular dilatation which did not progress into hydrocephalus following a documented haemorrhagic or ischaemic injury (Costello et al., 1988; Fawer & Calame, 1991). Their findings are contradictory. Whereas Costello et al. (1988) found 9 out of 18 children with ventricular dilatation (but no hydrocephalus) to have either developed some perceptuo-motor impairment at 4 years of age, no detectable long-term effects were reported in the 2 children studied by Fawer and Calame (1991). Apart from the small number of subjects involved in these studies, the lack of a precise definition of the extent of the dilatation

may account for the discrepancy in their findings. Although 'early' ventricular dilatation (as we found) and 'late' ventricular dilatation (arising in the neonatal period) may have different origins, it nevertheless seems that it is of interest to investigate whether there are any similarities in outcome between the groups.

Finally, we return to children with 'minor' ischaemic lesions. In contrast to severe parenchymal echogenicities which break down into extensive cystic lesions (periventricular and subcortical leukomalacia), the consequences of echodensities in the periventricular white matter, so-called 'flares', which either break down into small localized cysts or resolve completely are much less clear. In particular, little is known about the extent to which the duration of the flares is associated with later outcome. In a prospective study, Trounce et al. (1986) considered densities only to be relevant if they were present for at least 14 days. However, they provided no empirical evidence to support their view that flares which resolve earlier do not produce any impairment. In contrast, De Vries et al. (1988) found that flares lasting for less than 14 days did affect early neurological status in some children and Appleton et al. (1990) reported similar findings in a smaller study. In all of the above studies the children were followed for 3 years or less.

The long-term development of these children has been described by only 2 other research groups (Fawer and Calame, 1991; Levene et al., 1992). Fawer and Calame (1991) found children with small focal PVL to be significantly less competent in their performance on the McCarthy Motor Scale than those with normal scans. In contrast, Levene et al. (1992) could not detect a statistically significant difference in performance between children with prolonged flares and those with normal ultrasound scans on a previous version of the Movement ABC Test. However, these 2 studies concentrated solely on those whose densities persisted for at least 14 days. Apart from children with 'prolonged' flares, we have documented children in the present cohort who showed densities which resolved within 14 days.

Perceptuo-motor problems : a search for sub-groups

Throughout the literature on 'clumsiness' in children, variation in the pattern of perceptuo-

motor problems is frequently noted. However, despite observations of clinicians that, for example, one child seems to have more problems with manual dexterity tasks whereas another child's problems mainly centre around balance tasks, the question of whether the variation between children is systematic in any way has rarely been addressed. This contrasts sharply with attempts to understand other developmental problems such as dyslexia or hyperactivity where the question for sub-groups is well advanced both methodologically and theoretically.

From the few studies that do exist, it would seem that the notion of distinct sub-groups among children who experience perceptuo-motor problems is supported. However, the majority of studies on sub-grouping have been of a descriptive nature and it is only recently that various statistical techniques have been employed as a way of validating the existence of distinct individual profiles. Moreover, as far as we are aware, there has been no attempt within the follow-up literature to pull together the data of performance across the various perceptuo-motor measures in order to produce such profiles of weaknesses and strengths among individual or small groups of prematurely born children. Although we see our current attempt, described in Chapter 8, as exploratory, the variety of assessments employed and large number of children in the cohort allowed such an analysis.

Constructional skills - a detailed analysis of performance on a form board task

Few follow-up studies exist which go beyond the level of administering standardised assessments of perceptuo-motor performance. Although these assessments provide information on the level of competence achieved by the child at a certain age they do not allow for a more detailed examination of the processes involved in success or failure on a particular task. A detailed qualitative analysis of how premature children with perceptuo-motor difficulties perform a particular perceptuo-motor task has, to our knowledge, not been presented before.

We decided to select one particular task from our battery and use video analysis to obtain both quantitative and qualitative information of the children's performance. The idea of studying the children's performance on form boards originated from observations made

of the same cohort of children when they were assessed on the Griffiths Mental Development Scales in an earlier stage of this project. The paediatrician (LMSD) who assessed the children at regular intervals between birth and 2 years of life, noted that there were some children who had no observable difficulty in performing tasks which require fine manipulative activity, such as putting cubes into a box and putting the lid on the box, but did have marked difficulty with the age appropriate form boards. We thus wanted to explore whether this difficulty persists at the age of six and provide some additional information on what caused the children's failure.

Our choice of task was further influenced by reports in the literature which often mention but do not pursue the idea that prematurely born have difficulty with copying and drawing shapes. Among neuropsychologists, these difficulties, together with problems in constructing block designs or completing form boards, are often grouped under the heading of 'constructional dyspraxia'. At a processing level, what these tasks seem to have in common is the transformation of complex visual stimuli into a motor response. In the last Chapter of this thesis, Chapter 9, we address the question of how coherent these difficulties really are.

On the next two pages all the questions addressed in this thesis are presented.

QUESTIONS ADDRESSED IN THE THESIS

Chapter 6
- How do prematurely born children compare in their performance to that of a reference group on a number of neurological, perceptuo-motor, cognitive, behaviour and self-concept measures? - How do selected neonatal and demographic variables relate to perceptuo-motor competence within the premature group? - What is the prevalence of perceptuo-motor problems among our cohort?
Chapter 7
- Where do children with normal ultrasound scans fall on the continuum of perceptuo-motor problems? - What is the pattern of perceptuo-motor impairment among children with 'major' haemorrhagic and/or ischaemic lesions? - Are isolated 'minor' haemorrhagic or ischaemic lesions associated with later perceptuo-motor problems? - Does the co-occurrence of a 'minor' haemorrhagic and ischaemic lesion put a child at an increased risk for later perceptuo-motor problems? - Is the presence of ventricular dilatation at birth associated with poor perceptuo motor performance? - Is the duration of periventricular densities (flares) in the neonatal period associated with later perceptuo-motor competence? - Do groups of children with similar lesions show different profiles?
Chapter 8
- Is it possible to distinguish between sub-groups of premature children with perceptuo-motor problems? - What are the other characteristics of the sub-groups?

continued.....

Chapter 9
- Is the MASH form board a more challenging task than the Griffiths form board? - Which variables are associated with performance on the MASH form board? - Does a manipulation of the orientation of shapes affect performance? - Do children with constructional dyspraxia exist among our cohort? - What are the qualitative characteristics of the performance of children who have difficulty with the form board tasks?

CHAPTER 5

Subjects and Method

5.1 Introduction

This Chapter provides a comprehensive description of the children who participated in the study and the measures on which they were assessed at 6 years of age. Before beginning, however, it should be stressed that the cohort studied was highly selected and in no way represents a total population of premature children born in a specific region or hospital. Instead, the aim of the study was to gather longitudinal data on children whose early neurological status was fully documented. The developmental status between birth and approximately 2 years of age of most of the children participating in the present study has been the topic of a doctoral thesis by De Vries (1987) (LDV). In the present study we expand on her findings by reporting outcome at 6 years of age.

The Chapter is divided into 2 parts. In the first, the procedure for recalling, tracing and selecting the children at 6 years of age will be outlined. This is then followed by a description of the main characteristics of the final cohort including gestational age, birthweight, type and distribution of lesions as seen on ultrasound imaging, gender, ethnic origin and age at time of follow up. The second part of the Chapter then describes the assessment battery, the rationale for using these particular measures and, where appropriate, the pilot data collected.

Part 1 - Subjects

5.2 Subjects

Origin of cohort

Children participating in the study were all admitted to the Neonatal Intensive Care Unit (NICU) of the Hammersmith hospital and had nearly all been examined during their first two years of life by De Vries (1987). Table 5.1 shows the distribution of infants born at 34 weeks of gestation or less who were either locally booked, born at the Hammersmith hospital following in-utero transfer or referred to the NICU following delivery in a different hospital (ex-utero transfer). Except for infants who were booked into the Hammersmith hospital, the other infants were transferred back to the local hospital whenever their condition was considered stable. Infants who were admitted to the NICU between 1 January 1984 and 1 February 1986 were entered into the prospective study.

Table 5.1: Place of birth in relation to transfer (mortality; %).

place of birth	1984	1985 + Jan. 1986	
Inborn			
Local	56 (6; 10.7%)	64 (8; 12.5%)	
In Utero	110 (18; 16.4%)	83 (15; 18.1%)	
Outborn			
Ex Utero	53 (8; 15.1%)	41 (7; 17.0%)	
total	219 (32; 14.6%)	178 (30; 19.9%)	397 (62; 15.6%)

Selection criteria and final cohort size

When the children reached the age of 6 years, the list of children which had previously been studied was screened again and the paediatrician (LMSD) who was a co-director of the present study and the neonatologist (LDV) made the decision as to whether to recall the child for examination or not. This decision was based on four criteria: **1)** gestational age of 34 weeks or less **2)** a minimum of 3 cranial ultrasound scans 24 hours apart from each other **3)** no congenital abnormalities and **4)** a minimum of one examination in the Hammersmith follow up clinic at either 40 weeks postmenstrual age, or in infancy at 6, 9, 12, 18, or 24 months chronological age. Before the study commenced ethical permission was obtained.

The four selection criteria resulted in a cohort of **219** children (65 % of all surviving children born at 34 weeks or less between January 1984 and February 1986) who were eligible for inclusion in our study at 6 years of age. In Figure 5.1, a flow diagram of the stages involved in the selection of the children who formed the final cohort described in this thesis is presented.

Tracing procedure

For those children who fulfilled all four criteria, an intensive search was started to obtain their parents' most recent address and telephone number. As most children had not been seen after the age of 2 years, this meant contacting previous or current General Practitioners, numerous Family Health Services Authorities, and the Office of Population and Census Studies (OPCS).

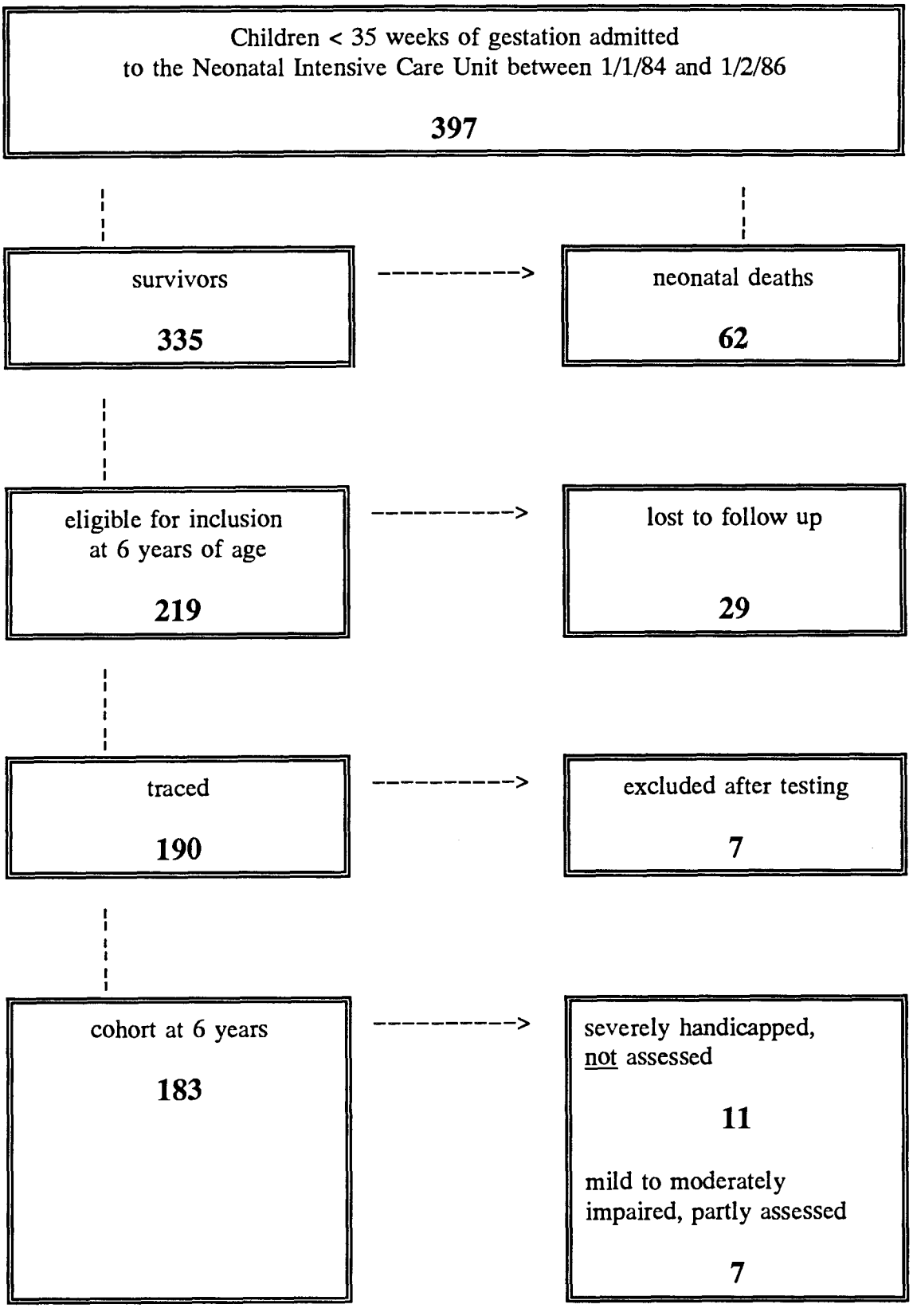

Figure 5.1: Flow diagram of cohort selection.

When the child was located, the paediatrician contacted the parents by telephone (if this was not possible a letter was sent), the purpose of the study was explained and parents were asked whether they would be willing for their child(ren) to participate. None of the parents which were traced refused co-operation. Thereafter, a letter was sent elaborating on the aims of the study and preparing both child and parent for the nature of the assessments to be carried out during their visit to the Institute of Education (see Appendix A).

Because four years had passed since the children were last examined in the follow up clinic it was not possible to trace all children. Given the great mobility of people living in large cities such as London, it came as no surprise that many families had either moved to a different address or even emigrated to a different country. A further complication that beset us was that many of the children who were difficult to find had changed their surname since they were last seen. This made identification very difficult although their N.H.S.-number was known. Even the OPCS was unable to trace some cases as the children did not appear in their records. Thus, despite our intensive efforts we were unable to trace **29** children (13%) leaving a total of **190** children (87%) who were candidates for participation in the study.

It was decided to exclude **7** children from the main analyses after they were examined at 6 years because they were found to suffer from other known medical conditions or had clinical signs which suggested that they may had a condition interfering with their development (e.g. Russell-Silver dwarf syndrome, severe autism, severe dysmorphic features). Therefore, **183 children** will be described from here on.

The paediatrician identified **11** children to be physically and/or mentally impaired to such a degree that it was highly unlikely they would be able to perform any or most of the tasks we intended to give to them. We did not examine these children at 6 years of age but felt it important to include them in some parts of this thesis in order to discuss the full range of impairments which may be associated with the presence of a brain lesion in prematurely born children. As in the study by Costello et al. (1988) it was decided to assign these 11 children a score of 3 standard deviations below the mean of

the premature cohort on all of the assessments.

In addition to the 11 children considered 'untestable', there were 7 children with physical or sensory impairments which were such that they could only be partly assessed at 6 years of age. Two children had a severe visual impairment and the remaining 5 children had severe motor difficulties which made it impossible for them to attempt some of the tasks set. For those components of the assessment battery these 7 children were not able to complete they were arbitrarily assigned scores equivalent to 2 standard deviations below the mean of the premature cohort. This was done in order to distinguish between severely and moderately impaired children.

Neonatal characteristics

Gestational age

As shown in Table 5.2, the children in the cohort (n=183) and those lost to follow up (n=29) did not differ in gestational age (X^2=0.17, df=2; p>.05).

Table 5.2: Distribution of gestational ages in weeks (%).

	N	25–27	28–29	30–32	33–34
Cohort at 6 years	183	30 (16%)	43 (23%)	83 (46%)	27 (15%)
Lost to follow up	29	4 (14%)	7 (24%)	14 (48%)	4 (14%)

Birthweight

As can be seen from Table 5.3, the groups did not differ in the distribution of birthweight (X^2=1.68, df=2; p>.05).

Table 5.3: Distribution of birthweight in grams (%).

	N	ELBW <1000	VLBW 1000–1499	LBW 1500–2499	NB >2500
Cohort at 6 years	183	40 (22%)	87 (47%)	54 (30%)	2 (1%)
Lost to follow up	29	4 (14%)	14 (48%)	11 (38%)	0 (0%)

Ultrasound scans and their classification

The ultrasound findings are summarized in Table 5.4. Scans were obtained, using an ATL Mark III mechanical sector scanner with a multifrequency scan head (5–7.5 MHz). Scans were done daily during the first week of life and twice a week thereafter until discharge.

Table 5.4: Ultrasound findings in cohort and those lost to follow up.

Ultrasound findings	cohort	lost to follow up
No abnormality	64	15
Grade I haemorrhage IIa haemorrhage IIb haemorrhage III haemorrhage	10 8 2 6	2 1 3 -
flares	45	7
flares and Grade I haemorrhage Grade IIa haemorrhage Grade IIb haemorrhage	10 8 2	- 1 -
Single small cyst	1	-
Ventricular dilatation	7	-
Infarct	2	-
Grade IIa haemorrhage, flares and infarct	1	-
Grade IIb haemorrhage and infarct	2	-
Grade IIb haemorrhage, flares, cyst, infarct	1	-
Extensive cystic periventricular leukomalacia	7	-
Cystic periventricular leukomalacia and Grade IIa haemorrhage Grade IIb haemorrhage	 1 1	 - -
Cystic periventricular leukomalacia, infarct, Grade IIb haemorrhage, cyst	1	-
Subcortical leukomalacia	3	-
Both cystic PVL/SCL	1	-
Total	183	29

The scans were then again performed whenever the child attended the follow up clinic, until closure of the fontanelle made this no longer possible. All ultrasound scans were assessed by one neonatologist (LDV). Haemorrhages were graded according to the classification system described by De Vries et al. (1985). Ischaemic lesions were defined as described by De Vries (1987) (see Chapter 1).
The proportion of children with or without abnormal ultrasound scans was similar among the children in the cohort and those lost to follow up (X^2=3, df=1; p>.05). Of the 7 children excluded from the study after assessment, five had a normal ultrasound scan. The remaining two children showed a Grade IIa haemorrhage in isolation, and a Grade IIa haemorrhage combined with flares, respectively.

Gender, ethnic origin and age at follow up

The original aim of this study was to examine the children between the ages of 6 years 0 months and 6 years 6 months. In 160 (87%) cases this objective was reached. However, for some children it took longer to either trace them or arrange an appointment for examination. This meant that 18 children (10%) were aged between 6 years 7 months and 6 years 11 months. In addition, 5 children (3%) had reached the age of 7 years before it was possible to examine them. Table 5.5 summarizes the gender and age distribution of the cohort.

Table 5.5: Distribution of gender and age (median; range).

Gender	Age (months)	N (%)
Boys	75 (73–87)	90 (49%)
Girls	75 (72–93)	93 (51%)
Total	75 (72–93)	183 (100%)

Table 5.6 shows the distribution of these children in terms of their ethnic origin. The largest group of children were Caucasian (75%), followed by children of Afro-Caribbean (16%) and Asian (9%) descent.

Table 5.6: Distribution of ethnic origin.

Gender	Ethnic origin		
	Caucasian	Afro-Caribbean	Asian
Boys	67	14	9
Girls	70	15	8
Total	137 (75%)	29 (16%)	17 (9%)

Part 2 - Method

5.3 General procedure

All children and their parent(s) were invited to the Institute of Education where a brightly lit room with a one-way mirror was reserved and all the necessary equipment for the assessments stored. After a short period of getting acquainted with the examiners and the environment the parent(s) was asked to leave the assessment room and sit in the observation room on the other side of the one-way mirror so that they could hear and see their child all the time. While waiting, the parents completed the behaviour questionnaire and the paediatrician interviewed them. All assessments were administered in a fixed order. In most cases, testing was completed within 2 1/2 to 3 hours. For those parents who found it difficult to visit us in Central London we arranged a hospital visit or a home-visit during school holidays or after the child had come home from school (n=29).

5.4 Assessment battery

Some work had been done on the selection of assessments for this project in the preparation of the research proposal, but when the study began it was nevertheless necessary to undertake some pilot work to finalise the battery. The amount of work necessary on each assessment varied considerably. For some we had to collect normative data or carry out reliability and validity checks, for others it was simply a case of reassuring ourselves that they were suitable for the children.

In Table 5.7 an overview of the assessments used in the main study is presented.

Table 5.7: Assessment battery at 6 years of age.

Area	Data gathered	Data reported		
		Chapter 6/7	Chapter 8	Chapter 9
Neurological status	Examination of the Child with Minor Neurological Dysfunction	total score	item scores	total score
Motor competence	Movement Assessment Battery for Children Test	total score	item scores	component scores and man dext. item score
	Movement Assessment Battery for Children Checklist	total score	total score	-
Constructional skills	I Developmental Test of Visual-Motor Integration	total score	total score	total score
	II Dot joining test	-	-	-
	III Draw-a-man	-	-	sub-scores
	IV Griffiths form board	time/errors	time/errors	time/errors
	V MASH form board	-	-	time/errors/shape analysis/ qualitative analysis
	VI Griffiths block design	-	-	time/errors
Vision	I Sonksen-Silver Acuity System	-	-	distant/near acuity
	II Stereo Test	-	-	stereoscopic vision present/absent
Visual discrimination	I Matching Letter-Like Forms (BAS)	-	-	total score
	II triangle test	-	-	-
	III shapes of MASH form board	-	-	time/errors/shape analysis
Cognitive ability	British Ability Scales: Matrices, Similarities, Naming Vocabulary, Digit Span	short-form IQ	short-form IQ	verbal ability score (Similarities + Vocabulary)
Reading	Word Reading (BAS)	total score	-	-
Behaviour	Rutter Scales for parents and teachers	total score	total score	-
Self-concept	Pictorial Scale of Perceived Competence and Social Acceptance	sub-scores	sub-scores	-
Demographic variables/ history	Questionnaire	SES	-	-

The assessments can be divided into three groups. The first group comprises assessments which form the *main focus of this thesis*, namely those examining neurological status and perceptuo-motor competence. Apart from the Dot joining test and the MASH form board, all measures included in this group are well-known. The second group are assessments of a more specific nature investigating the children's vision and visual discrimination. They included a mixture of well-established assessments (the Sonksen-Silver Acuity System, Stereo Test and Matching Letter-Like Forms) and assessments which have never been used before in similar follow up studies (triangle test and matching shapes from the MASH form board). The third group of assessments provides us with information of a general character which will mainly be considered as background information. Apart from the interview with the parents, these are all standardized assessments which have been used in similar studies. Throughout the thesis these background variables are discussed under the arbitrary heading of 'associated problems'.

5.4.1 Neurological status and perceptuo-motor competence

Neurological status

When a standardized assessment has been included in a research-project on children born prematurely, one of the most commonly used has been the Examination of the Child with Minor Neurological Dysfunction developed by Touwen (2nd Edition, 1979). This assessment was designed quite specifically to detect subtle difficulties and is based on Touwen's view of central nervous system development. However, because of the detailed and lengthy nature of the Examination it is not surprising that only a few studies have used the complete version (e.g. Largo et al., 1989; Marlow et al., 1990). Many studies administered only parts of the Examination (e.g. Noble-Jamieson et al., 1982; Astbury et al., 1987; 1990), while others administered a modified version (e.g. Rickards et al., 1987). In the present study only one part of Touwen's Examination was omitted and this was because a more comprehensive measure of the same function was included in the assessment battery.

In Part 1 of this Chapter it was stated that 11 children were impaired to such a degree that they would not have been able to complete the assessment battery we chose to administer.

Ideally, we should have evaluated these children's motor performance on measures specially designed for children with impairments such as, for example, the Motor Control Assessment (Steel et al., 1991) or the Physical Abilities Chart (Levitt, 1982). However, including these measures was impossible given the resources available.

Assessment description and procedure

Each child was seen by the paediatrician (LMSD) who administered the items as described by Touwen (1979). The Examination consists of a range of items arranged under the following cluster headings: sensorimotor apparatus, posture, balance of trunk, coordination of the extremities, fine manipulative ability, (dys)kinesia, gross motor functions, quality of motility, associated movements, and the visual system. The complete version of Touwen's Examination includes a total of 62 items. In the present study, 16 items were omitted for two reasons. Since an evaluation of vision formed part of the study, these items along with the others forming the last cluster were excluded. Also, assessment of the abdominal skin reflex was omitted as children objected to it. Table 5.8 summarizes all the 46 items of the neurological Examination included in the main study.

Data recorded/obtained

A raw score for performance on each item is obtained according to the scoring system described by Touwen (1979). These raw scores are then converted to optimality scores. Optimal performance on an item represents perfect performance and is given a value of 1. All ranges of non-optimal performance are given the score of 0. The sum of these optimality scores result in a total optimality score. Furthermore, in order to analyze the neurological status of the child in more detail, optimality scores may be calculated for each cluster separately.

Normative data

Touwen (1979) recommends that the user "..try and find his own norms for his own population for many of the items .. in order to interpret his findings reliably" (p. 3). We, therefore, collected our own 'normative' data on a reference group of 6-year-old children from mainstream schools matched on age, gender and ethnic origin to the premature group. In addition, inter-tester and test-retest reliability as well as construct and

concurrent validity were investigated (see Kakebeeke et al., 1993 and Schoemaker et al., submitted).

Table 5.8: Items administered from Touwen's (1979) neurological Examination.

Sensorimotor apparatus resistance to passive movements; muscle power; range of movements; muscle consistency; leg reflex threshold and intensity; arm reflex intensity and intensity; foot sole reflex
Posture sitting, general; feet, sitting and standing; standing, general; legs, standing; walking; lying in prone and supine position
Balance of trunk response to push, standing; following an object with eyes and head; Romberg sign; walking in a straight line
Coordination of extremities fingertip–nose test; diadochokinesis; knee–heel test; kicking against the examiner's hand; fingertip–touching test;
Fine manipulative ability finger–opposition test; follow–a–finger test; circle test
(Dys)kinesia choreiform movements distal, proximal, and during spontaneous movement; athetotiform movements; other (dys)kinesias
Gross motor functions heel–toe gait during walking; walking on tiptoe and heels; standing and hopping on one leg; rising to sitting from lying
Quality of motility quality, smoothness and adequacy of small and gross movements
Associated movements mouth–opening finger–spreading phenomenon; accompanying diadochokinesis, walking on heels and finger opposition

Subjects

Sixty–four children from 5 different schools in and around London were examined. As these normative data were collected after we finished testing the premature cohort it was possible to match the school children (percentage wise) on age, gender and ethnic origin.

Results

Table 5.9 shows the distribution of total optimality scores obtained by the reference children. The median optimality score was 40.5 (range=31–46).

Table 5.9: Distribution of neurological optimality scores for the reference group.

Total optimality score	N	Cumulative percentage
31	1	1.6
32	1	3.1
34	3	7.8
35	4	14.1
36	4	20.3
37	4	26.6
38	2	29.7
39	4	35.9
40	9	50.0
41	7	60.9
42	6	70.3
43	9	84.4
44	4	90.6
45	4	96.9
46	2	100.0

General motor competence

In order to obtain a measure of the children's motor competence, the Movement Assessment Battery for Children Test (Henderson and Sugden, 1992) (previously named the Test Of Motor Impairment and first developed by Stott et al. in 1972) was included in the study. Although other assessments exist, such as the Bruininks–Oseretsky Test of Motor Proficiency (Bruininks, 1978) the Movement ABC Test was chosen because it has been widely used in Great Britain for many years and has recently been administered to cohorts similar to our own (for example, Jensen et al., 1988; Marlow et al., 1989; The Scottisch Low Birthweight Study Group, 1992; Nickel et al., 1982).

Assessment description and procedure

The Movement ABC Test is divided into four Age Bands ranging from Age Band 1 for

4- to 6-year-olds, to Age Band 4 for children aged 11 years and older. For the present project children are assessed on all the items of Age Band 1 as described in Table 5.10. Each Age Band contains 8 items: 3 items testing manual dexterity, 2 items testing ball skills, and 1 item testing static and 2 items testing dynamic balance.

Data recorded/obtained

Performance on each item of the Test can be scored on a 5-point scale each representing a particular centile point based on the performance of the standardization cohort. Scores range from 5 (bottom 2.5%), 4 (bottom 5%), 3 (bottom 7.5%), 2 (bottom 10%), 1 (bottom 15 %) to 0 (remaining 85% of the cohort). This type of scoring reflects the purpose of the Test, namely to identify children who have motor problems as opposed to identifying the highly athletic child. A total motor competence score is obtained by simply adding the scores for each item. Total scores range from 0 to 40, with 0 meaning that the child is well-coordinated and a score of 40 that a child is poorly coordinated for his/her age. Also, a distinction can be made between manual dexterity, ball skills and balance ability by adding the scores of the different categories.

Normative data

Since no UK norms are yet available for this latest edition of the Movement ABC Test, a pilot study was conducted to compare the distribution of scores for a reference group of British children with that of the American children of the same age.

Subjects

The Movement ABC Test was administered to 88 children (47 boys, 41 girls) believed to be without any developmental abnormalities recruited from six schools in London and Leeds. Five were state schools, one was a private school. Their mean age was 76.2 months (SD=2.7). The American standardization cohort consisted of 136 children (75 boys and 61 girls) with a mean age of 77.4 months (SD=3.3).

Table 5.10: Items of the Movement Assessment Battery for Children Test.

TASK	RECORDED
Manual dexterity	
1. *Posting coins* The child is required to drop 12 coins through the slot in the bank box as quickly as possible. Both the preferred and non-preferred hand are tested.	Number of seconds
2. *Threading beads* The child is required to thread 12 cube-shaped beads on a lace as fast as possible.	Number of seconds
3. *Bicycle trail* The child has to draw a single continuous line, following the trail without crossing its boundaries. Only the preferred hand is tested.	Number of errors
Ball skills	
4. *Catching bean bag* The child has to catch a bean bag tossed at him by the examiner from a distance of 2 metres.	Number of catches out of 10 attempts
5. *Rolling ball into goal* The child has to roll a tennis ball along the floor between jumping stands which are placed 40 cm apart at a distance of 2 metres from the starting line behind which the child kneels.	Number of goals out of 10 attempts
Static and dynamic balance	
6. *One-leg balance* The child is asked to stand on one leg for up to 20 seconds. Both legs are tested.	Number of seconds
7. *Jumping over cord* From a stationary position with feet together, the child has to jump over a cord placed at knee-height.	Pass/fail for a(n) (un)successful jump
8. *Walking heels raised* The child has to walk along a 4.5 metres long line with heels raised without stepping off the line.	Number of correct consecutive steps

Results

T-tests for independent samples (two-tailed) were applied. Data analysis was based on the best trial for each item. Table 5.11 shows the results of this comparison.

Table 5.11: Performance of American and English children on the items of the Movement ABC Test (mean; SD).

Item	American (n=136)	English (n=88)	p^
Posting coins (sec)			
Pref. hand	17.13 (3.82)	16.76 (1.87)	ns
Non-pref. hand	19.12 (4.12)	18.93 (2.52)	ns
Threading beads (sec)	41.64 (10.03)	43.83 (8.14)	ns
Bicycle trail (errors)	0.41 (0.80)	0.02 (0.15)	***
Catching beanbag (catches out of 10)	8.76 (1.64)	9.10 (1.30)	ns
Rolling ball (goals out of 10)	7.42 (1.91)	7.41 (2.12)	ns
One-leg balance (sec)			
Right leg	16.81 (5.10)	18.38 (3.51)	**
Left leg	16.24 (5.23)	18.40 (3.11)	***
Jumping over cord			
pass knee height	130	86	ns
pass lower height	5	1	
fail	1	1	
Walking on tip-toe (steps out of 15)	14.18 (2.06)	14.58 (1.36)	ns

^ t-test except for Jumping over cord: $X^2=1.41$, df=2, $p>.05$

From this Table it can be seen that the groups were very similar in their performance on 6 out of the 8 items. The two items on which the American children were performing more poorly than their English peers were the bicycle trail and the one-leg balance task.

The range of scores on the bicycle trail item for the American and English groups were, however, comparable (0–5 and 0–6, respectively). Similarly, the range of scores for the two groups on the one-leg balance items were alike (3–20 and 4–20, respectively). One reason for why the American children were worse on this manual dexterity task may be that these children, on average, start formal schooling slightly later and have less experience in handwriting. Why the English children were better in their static balance is unclear.

Overall, the performance of the reference group of 6-year-old school children tested in England was similar on the items of the Movement ABC Test to that of their American peers. The differences between the groups were not large enough to adapt the original scoring system.

Constructional skills I: Developmental Test of Visual-Motor Integration

Earlier studies of prematurely born children have frequently used the Bender Gestalt as a tool to investigate the prevalence and severity of visual-motor problems among these children (e.g. Francis-Williams & Davies, 1974; Lis, 1969; Wiener et al., 1968). However, instead of the Bender Gestalt we have chosen to administer the Developmental Test of Visual-Motor Integration (VMI) developed by Beery. This assessment was chosen for two reasons: it has fairly recent norms (i.e. 1982) and is commonly used in follow up studies of prematurely born children conducted after 1980 (e.g. Klein et al., 1985; Robertson et al., 1990; Sostek, in press; Vohr & Garcia Coll, 1985).

Assessment description and procedure

The assessment consists of the child copying a sequence of 24 forms which become increasingly more difficult. First the child is required to copy single forms such as a circle, square and triangle. Later on the forms become more complex and consist of two or more shapes which have a special spatial arrangement. The child is asked to copy the shapes until he/she fails three consecutive drawings. Figure 5.2 shows a number of geometric shapes included in the VMI.

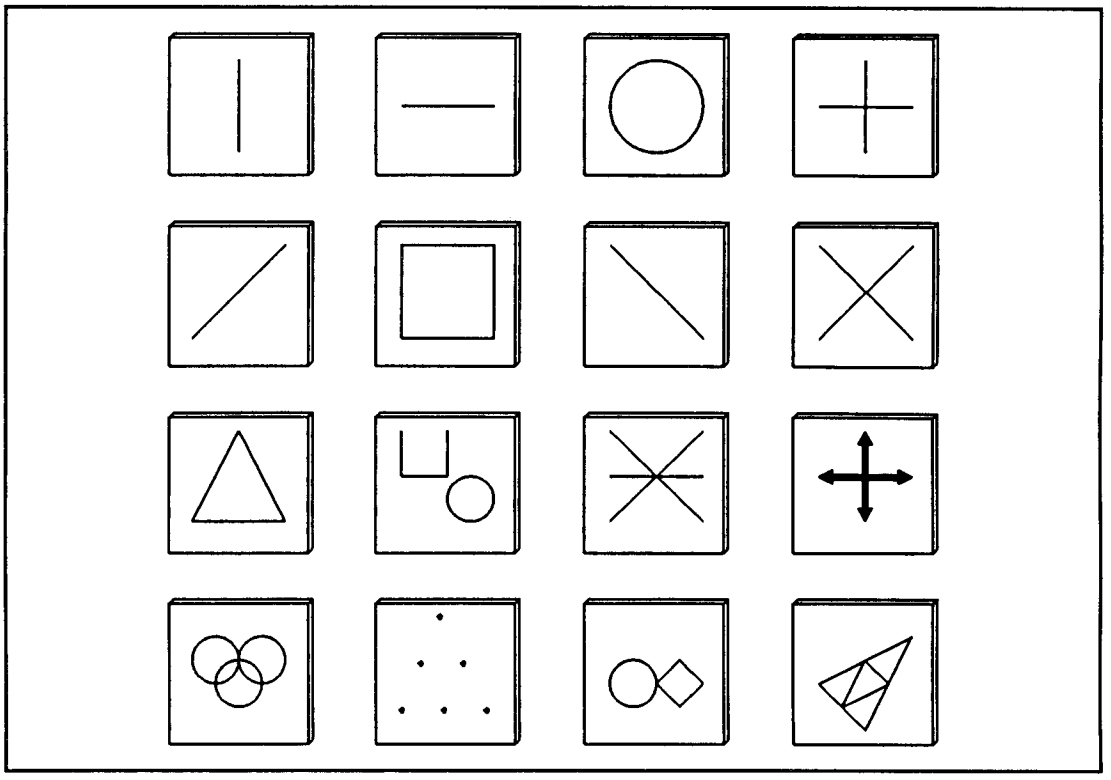

Figure 5.2: Examples of some geometric shapes included in the Developmental Test of Visual-Motor Integration (Beery, 1982).

Data recorded/obtained

Each drawing is scored according to several criteria described by Beery (1982). The child either passes or fails a drawing. The raw score consists of the total number of passes (minimum 0 - maximum 24). This score is transformed to a standard score and percentile point. In addition, the assessment provides age-equivalent scores.

Normative data

To the best of our knowledge the VMI has never been administered to a large group of normal English children. We, therefore, set out to investigate whether the scores obtained by 6-year-old English children on the VMI are comparable to those obtained by American children of a similar age.

Subjects

Sixty children, randomly selected from two schools in Hatfield, Hertfordshire were asked to complete the test. Twenty-nine were boys and 31 were girls. Their ages ranged from

6 years 0 months to 6 years 11 months. Mean age was 77.4 months (SD = 3.2). Eleven children preferred to draw with their left hand. Two children were tested at the same time.

Results

The drawings were scores according to the criteria described by Beery (1982). The American standardization cohort consisted of 210 six-year-olds similar in age range to our own cohort. Figure 5.3 illustrates the distribution of raw scores of the English and American cohorts. The mean raw score for the English cohort was 11.38 (SD=1.98) and for the American cohort this was 11.79 (SD=2.60). A t-test for independent samples (two-tailed) showed no difference between the two groups (t=1.29, p>.05).

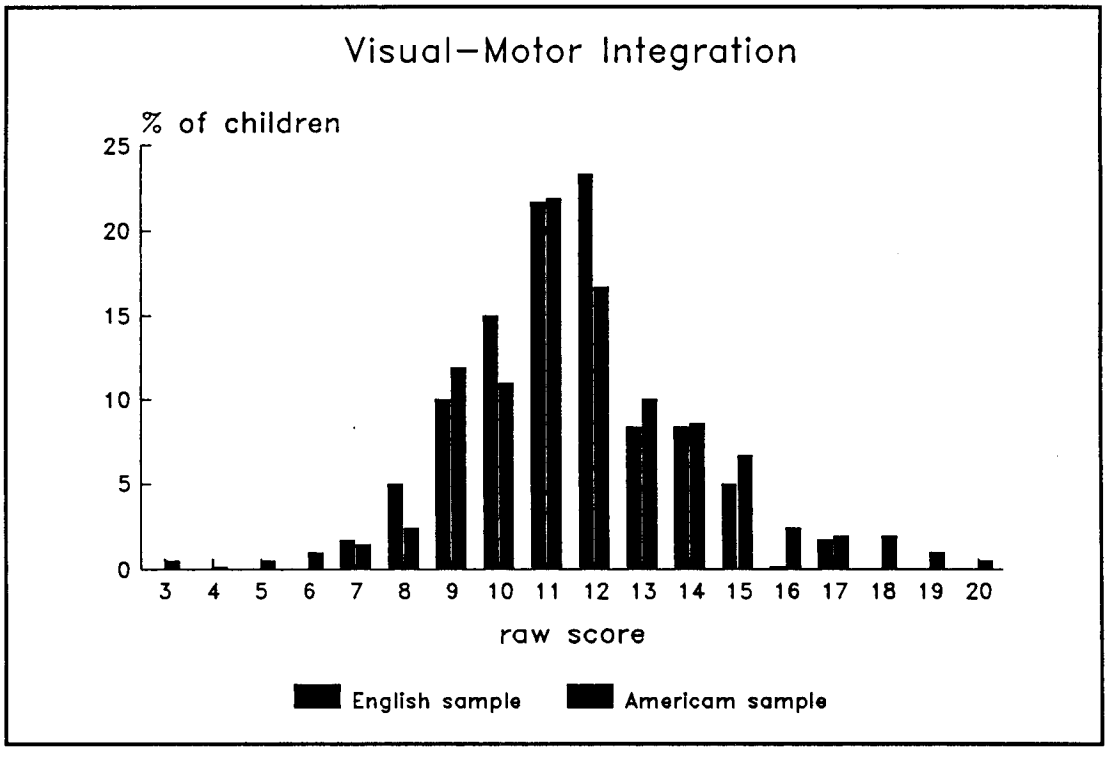

Figure 5.3: Distribution of raw scores on the Developmental Test of Visual-Motor Integration for the English and American children.

Reliability

Inter-scorer reliability of the test was also investigated. Apart from the author (MJ) who scored the drawings of all the children an independent observer (RS) was asked to score the drawings of 20 randomly selected prematurely born children. The results showed that

out of the 334 drawings scored the two raters only differed in their opinion on 21 drawings, i.e. the percentage of agreement calculated as: number of agreements/ (number of agreements + disagreements) was 94. Since no difference in the distributions of raw scores emerged between the groups we can, therefore, convert the raw scores of the English children into the standard scores as described by Beery (1982).

Constructional skills II: Dot joining test

In addition to the Developmental Test of Visual–Motor Integration, we wished to include a geometric shape copying task in which the visual input needed to complete the task was experimentally manipulated. Therefore, we have attempted to design a task which we think may reveal in more detail the nature and severity of the problems premature children may have with representing shapes on paper and called it the Dot joining test.

A similar task is included in the Frostig Developmental Test of Visual Perception (Frostig et al., 1961). Subtest V of this test (Spatial Relations) involves the copying of 8 non–figurative line figures in a regular pattern of dots. The child is provided with the same pattern of dots without the lines and is required to draw lines between the dots to imitate the model figures. Furthermore, Birch and Lefford (1967) included a task in which children (aged 5 to 11 years) had to draw geometric shapes on a dot grid resembling a model on a stimulus card.

Assessment description and procedure

In our newly devised Dot joining test the children were asked to copy a square, triangle and cross which are all drawn in black ink on a background of black dots. Figure 5.4. shows the configuration of the test. These 3 shapes were chosen as they are all included in the Developmental Test of Visual–Motor Integration (although the cross is slightly adapted here) and are all part of the Griffiths form board (see later).

Data obtained/recorded

In our view, simply counting the number of correctly joined dots as suggested by Frostig et al. (1961) is a rather unsatisfactory reflection of the quality of the drawing. When Abercrombie et al. (1964) administered the Spatial Relations subtest to various groups of

children with cerebral palsy, she too noted that it was much more useful to describe performance in terms of the type of errors made. Following their comments and those of Birch and Lefford (1967) we devised our own scoring system. This system centred around three criteria:

1) whether the shape is correct/incorrect; a correct shape is defined as: square=four clearly defined sides; triangle=three clearly defined sides, one corner higher than others; cross=four clearly defined arms, midline of opposing arms within 10 degrees of the vertical and horizontal orientation.
2) accuracy of joining the dots: whether the child touches all dots or misses two or more on the grid
3) whether the size of the drawing is correct/incorrect; a shape roughly one-third as large or small as the model is regarded as incorrect.

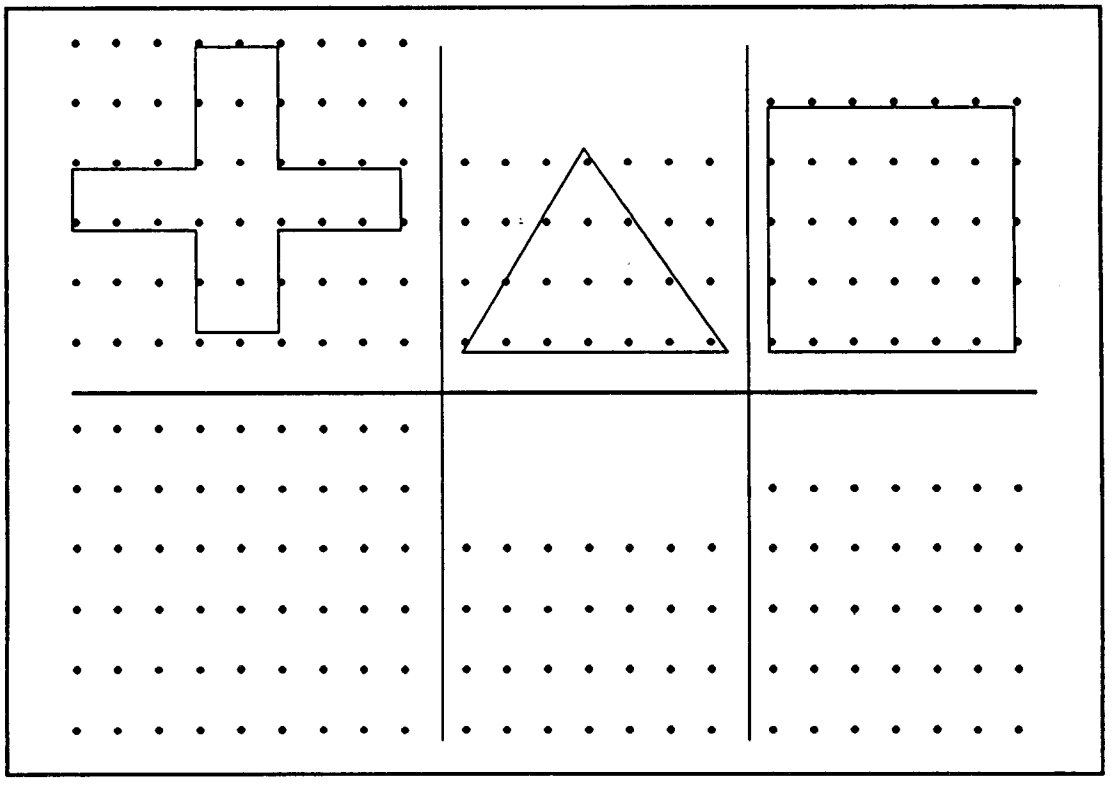

Figure 5.4: Stimulus shapes in the Dot joining test.

Reason for <u>not</u> incorporating Dot joining data in this thesis

Although we did assess approximately 70 children on this experimental drawing task, we had to abandon assessing the remainder of the cohort on this particular measure due to time pressure, a lack of funding to check reliability of the scoring system and to gather data from a reference group.

Constructional skills III: Draw-a-man

Although part of the school curriculum, copying of geometric shapes is probably a less spontaneous activity for the child compared to, for example, drawing animals or humans. Therefore, the last drawing task included in the assessment battery, the drawing of a human figure, was chosen to supplement the information yielded by the other drawing tasks. For this purpose we chose the well known Goodenough-Harris Draw-a-man (Harris, 1963).

Assessment description and procedure

The child was given a blank sheet of white paper and a pencil and asked to draw the best man they can. Children were encouraged to continue until they felt their drawing was completed.

Data recorded/obtained

Rather than calculating a standard score as originally proposed by Harris (1963) we followed the example by Barnett and Henderson (1992) who subdivided the composite scores into four components, each representing a different aspect of performance: 1) motor control and coordination 2) representation of proportions 3) the depiction of particular features, and 4) the awareness of detail in any feature [1] . In this way, a more informative description was obtained of the child's performance. Using this system, each drawing was scored by a rater (NS) who was not involved in the assessment of the children.

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[1] *This more detailed description of the drawing of a human figure was first proposed by O'Connor and Hermelin (1987).*

Constructional skills IV: Griffiths form board

Form boards are a familiar tool in psychology to examine a child's perceptuo–motor development. One of the best known, the Seguin form board, was included in assessment batteries as far back as 1923 (Pintner–Paterson Performance Scale). The Seguin form board consists of ten insets to fit forms level with the board. Another, the Goddard board is similar to the Seguin except that the forms do not fit level with the board. In this study the children were given two form boards to complete: the form board from the Griffiths Mental Development Scales and a form board called the MASH which was specially devised for this study.

Assessment description and procedure

The shapes of the Griffiths form board vary from a circle and square to more complex shapes such as an asymmetrical triangle. The shapes were presented together in a standard format next to the base of the form board in such a way that the child only needed to lift the shape and transport it to the correct cavity in the base without changing its spatial orientation. This procedure slightly differs from the one Griffiths describes in her manual. However, we felt it was necessary to introduce this more structured approach to facilitate later analysis. The children were asked to complete the task as quickly as possible. In Figure 5.5 the standard lay–out of the shapes as well as the base of the form board showing the location of the cavities is depicted.

Data recorded/obtained

Apart from time taken to complete the task, the number of errors made by each child was recorded. An error was defined as an attempt by a child to insert a shape into the wrong cavity (e.g. symmetrical triangle in the asymmetrical triangle cavity). Only those attempts in which the shape physically touched the wrong cavity were counted as errors. In order to examine in more detail the type of error made, a special record sheet was designed which allowed the examiner to record which cavity the child attempted to put a shape in. A video tape was made of those children who were assessed at the Institute of Education (it proved to be too difficult to obtain a proper recording of children seen at their homes).

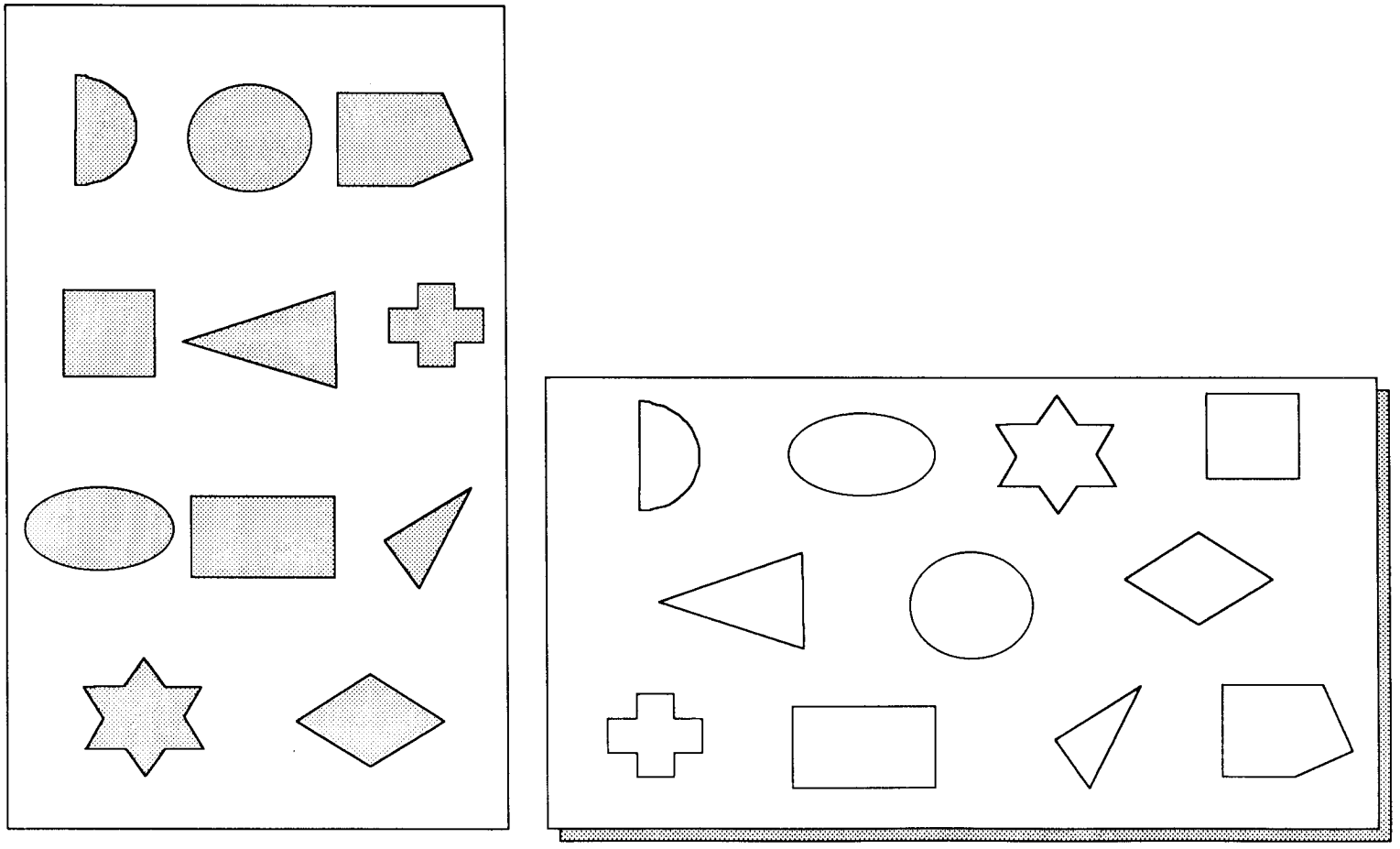


Figure 5.5: Shapes of the Griffiths form board as they were presented to the child (left-hand side) and the board (right-hand side).

Normative data

Griffiths (1967) has established norms for the form board in terms of time to complete for children at different ages. At the age of six, the children are expected to complete this task within 40 seconds. However, there are no norms available regarding the number of errors children at different ages make. We decided, therefore, to assess a random cohort of school children in the same age range as the prematurely born children to 1) check the time-norm and 2) to establish norms for number of errors made.

Subjects

Sixty-four children (33 boys; 31 girls) believed to be without any developmental abnormalities, were recruited from six schools in London and Leeds. Five were state schools, one was a private school (Leeds). The children ranged in age from 6 years 0 months to 6 years 10 months. Mean age was 75.9 months (SD=2.8).

Results

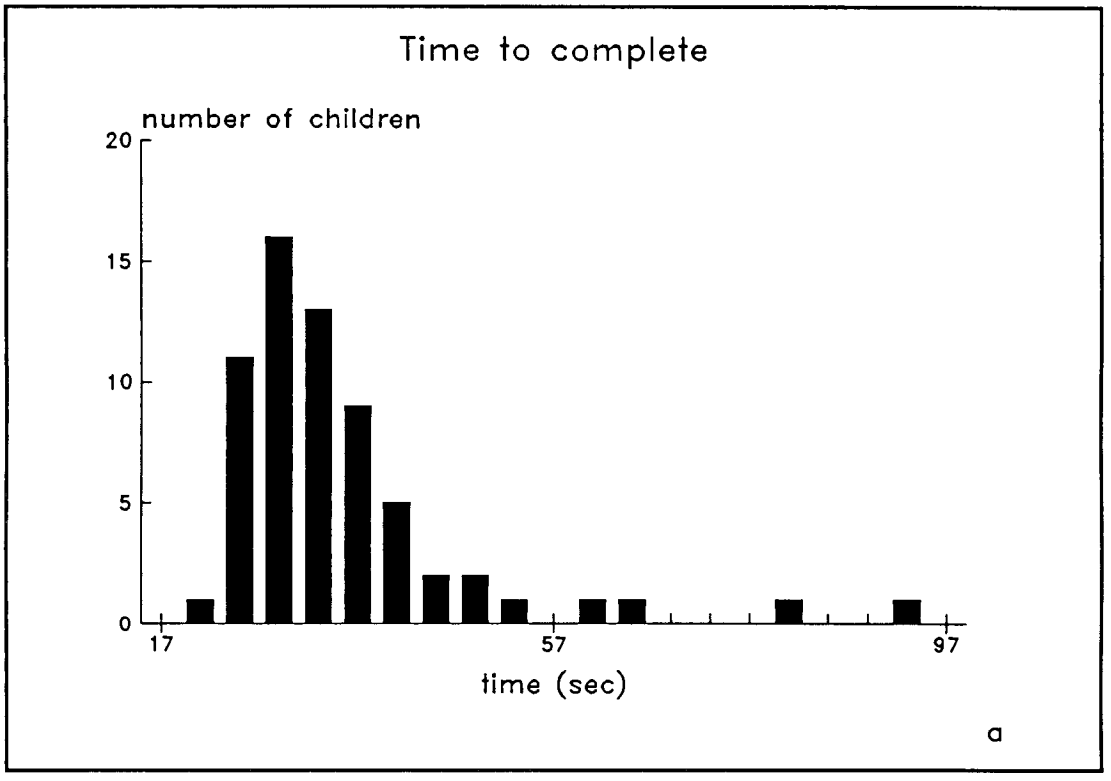
Figure 5.6 shows the distribution of seconds it took the children to complete the task as well as the number of errors made. Median completion time was 32 seconds (range=20-94) and the median number of errors made was 0 (range=0-2). Table 5.12 shows the various percentile points for time taken to complete.

Table 5.12: Selected percentile points for time taken to complete the Griffiths form board from distribution of the reference group.

Seconds	Percentile point
61	5
47	10
42	15
31	50

Reliability

To investigate the degree of inter-observer reliability for errors made, a second observer (RS) was asked to analyze the performance of 20 randomly selected prematurely born children on the Griffiths form board from the video tapes.



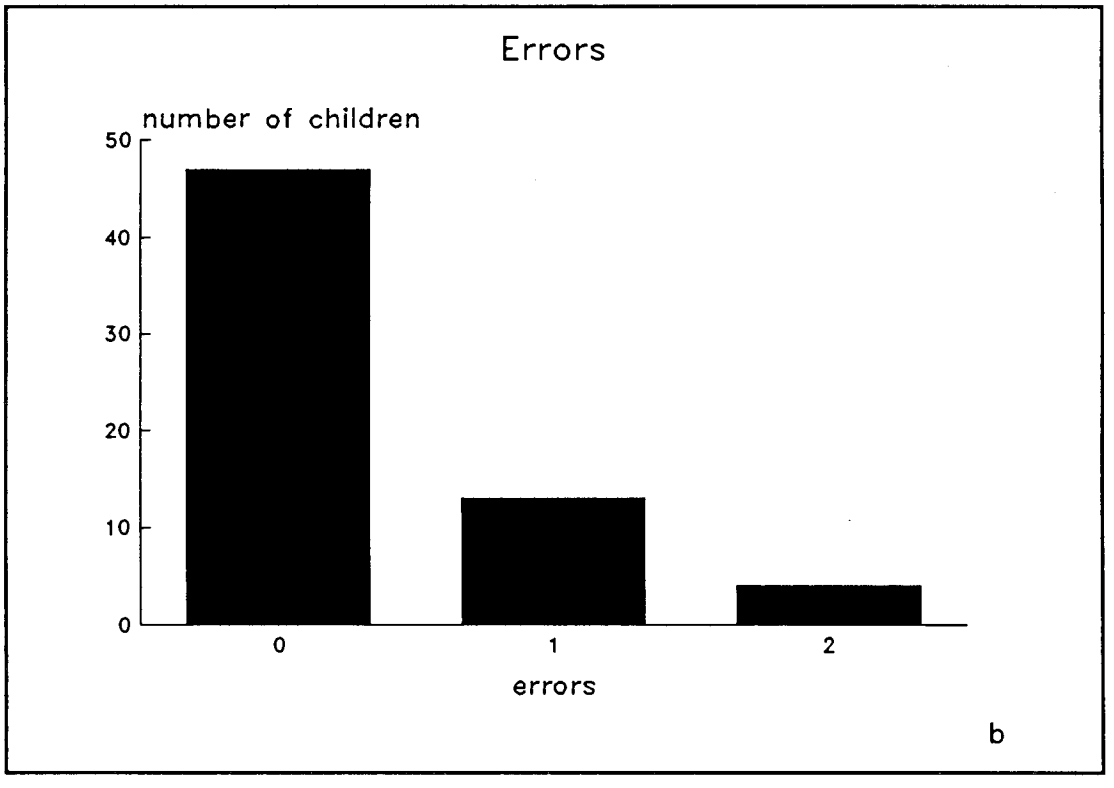


Figure 5.6: Distribution of time taken to complete (a) and number of errors made (b) on the Griffiths form board for the reference group.

The results show that out of a total number of 220 observations (20 children x 11 shapes) the overall number of disagreements was five: the second observer saw 2 errors which were not detected by the first observer, while vice versa the number was 3. The percentage of agreement, calculated as number of agreements/ (number of agreements + disagreements), was 98%.

The majority of this reference group of 6-year-olds completed the form board within the time limit of 40 seconds as described by Griffiths (1967). Ten children (16%) did not reach this criterion. Few children made errors and inter-tester reliability for number and errors made was good.

Constructional skills V: MASH form board

From previous clinical experience it was known that it would be fairly easy for 6-year-olds to insert the shapes included in the Griffiths form board. As many premature children (even without major impairments) appear to have rather subtle difficulties we were concerned that this task would not be sensitive enough to detect differences between premature and 'normal' 6-year-olds. To investigate performance at a more complex level of shape discrimination we set out to design a new form board taking the shapes included by Griffiths as a starting point. When constructing the new form board we had two aims in mind. Firstly, we wanted to increase the overall level of difficulty. Secondly, we wished to investigate the process of performing the task in a systematic way.

Pilot studies

1) Intermediate form board

There are several ways in which the overall level of shape discrimination can be made more difficult for the child. For example, an element of confusion can be introduced by constructing a second shape which is similar to the original shape but differs in one or more characteristics such as size or detail. Initially, out of the 11 shapes included in the Griffiths form board a random selection of 6 shapes was made and for each of these a 'twin' shape was constructed which differed in detail (rather than overall size) from the original shape. The resulting 6 pairs of shapes are depicted in Figure 5.7.

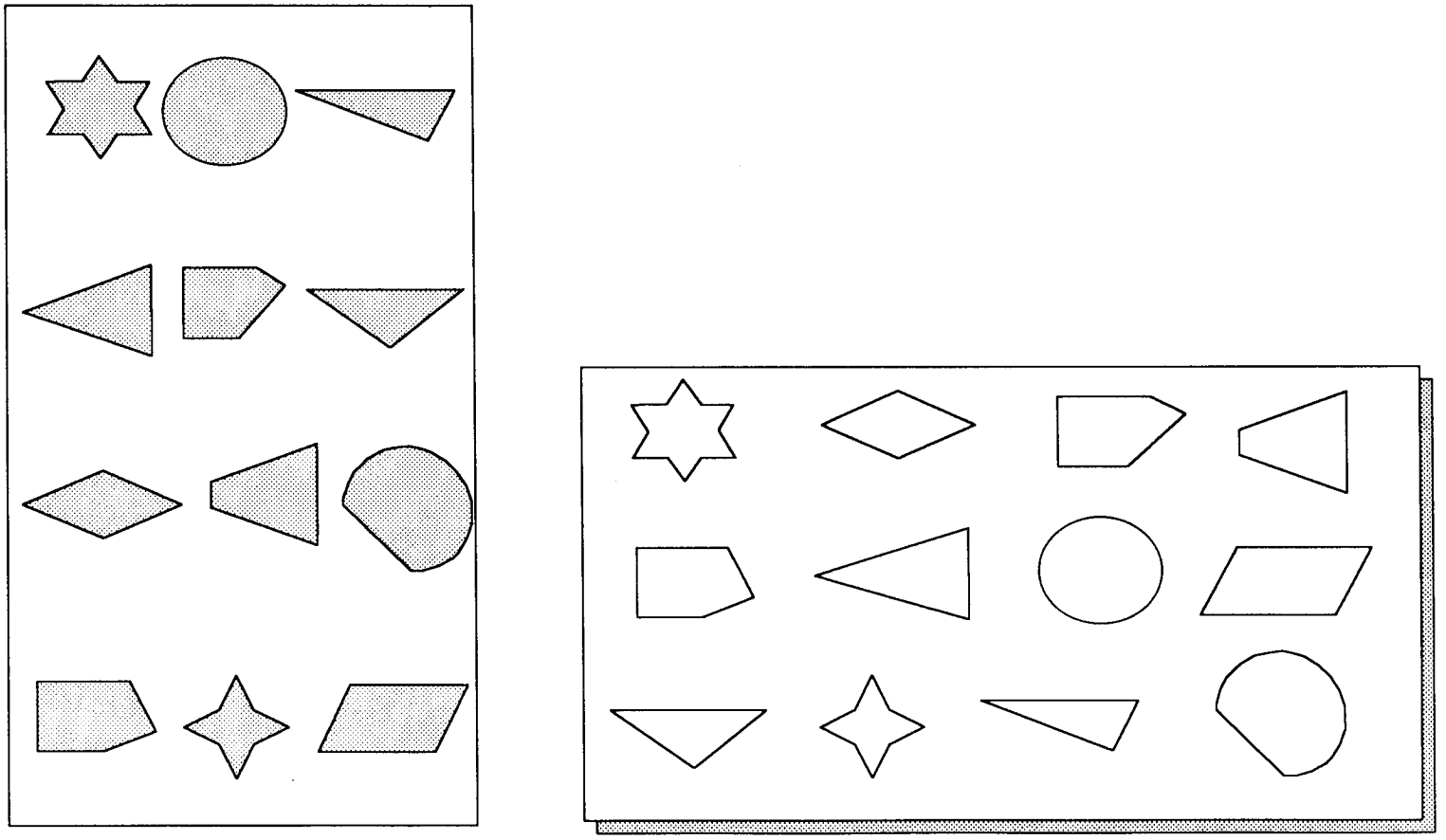


Figure 5.7: Shapes of the Intermediate form board as they were presented to the child (left-hand side) and the board (right-hand side).

Shortly before testing of the premature children began, the Griffiths form board and this new form board were presented to 20 randomly selected children from a nearby school to get an idea of the speed and accuracy with which these children completed the new form board. Children were also asked what they thought about the new form board (i.e. was it more difficult then the Griffiths form board? Which pairs of shapes were most easy or difficult to discriminate between?) From this pilot testing it became clear that 4 pairs were very easy to discriminate (hardly any errors made and no hesitation while inserting). Consequently, 4 additional pairs of shapes were designed. By this time, testing of the premature children had started and it was decided to abandon further pilot testing to ensure that all premature children completed the same form board task which was named the **MASH form board**.

2) MASH form board

Assessment description and procedure

The final version of the twelve-hole MASH form board was made, with the base made of light brown wood, while the shapes were made of dark brown wood. For ease of handling the shapes protruded slightly. There were six pairs of shapes. While one of each pair was a shape which most children are familiar with, i.e. star, cross, diamond, symmetrical triangle, asymmetrical triangle and house, the other was a slight adaptation (e.g. a star which has six points is matched with a star which has 8 points). Figure 5.8 shows both the shapes as well as the base of the MASH form board.

All twelve shapes were presented in a fixed format next to the base of the form board in their normal orientation (i.e. corresponding to the orientation of the cavity in the board). The children were instructed to insert the shapes in the cavities as quickly as they could.

Data recorded/obtained

Time taken to complete the task was recorded. Also, the number and type of errors were noted on the specially designed record-sheet and a video tape was made for those children we tested at the Institute of Education.

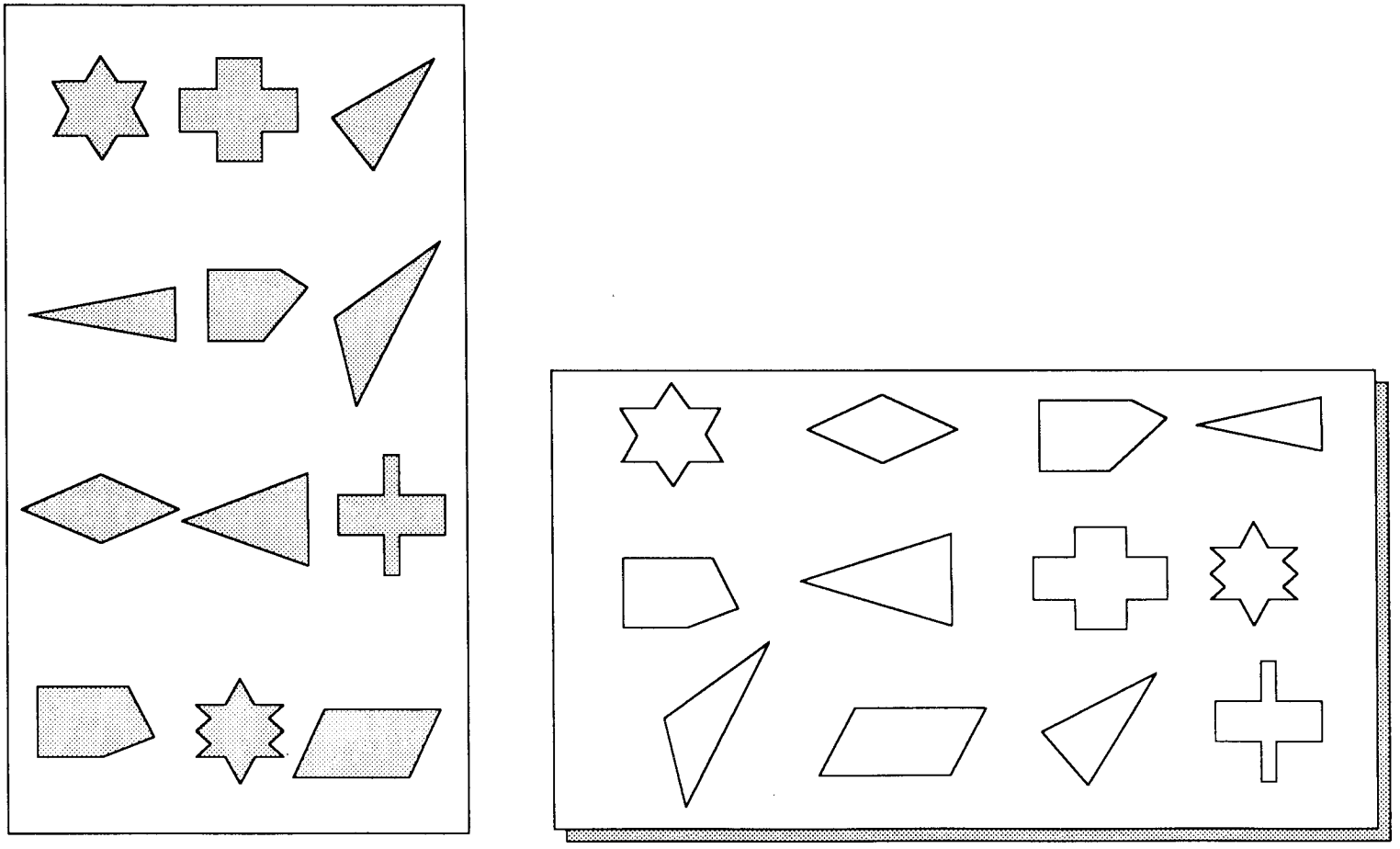


Figure 5.8: Shapes of the MASH form board as they were presented to the child (left-hand side) and the board (right-hand side).

Normative data

As this was a newly developed task no norms existed for time to complete or number of errors made. In order to be able to evaluate the performance of the prematurely born children in relation to their normal peers we, therefore, assessed a reference group on this task.

Subjects

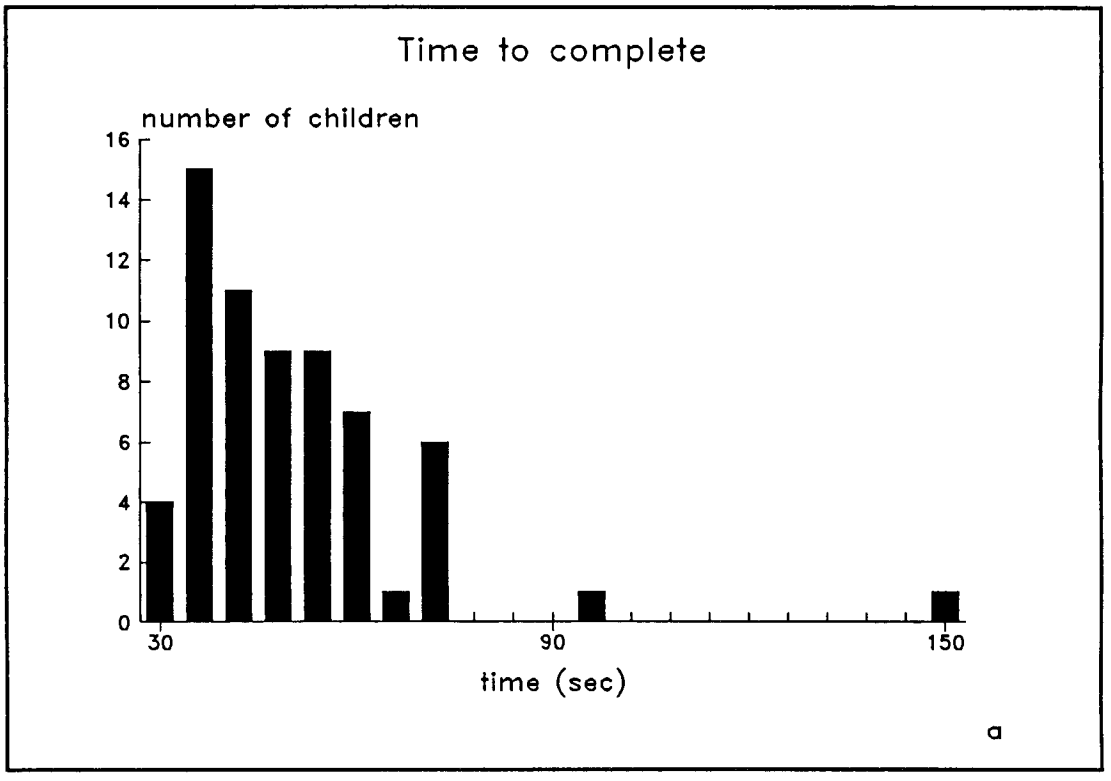
The same reference group of 6–year–olds who completed the Griffiths form board were assessed on the MASH form board.

Results

Figure 5.9 shows the distribution of seconds it took these children to insert the shapes and the number of errors made. Median time to complete this task was 45 seconds (range=29–150). The median number of errors made was 2 (range=0–6). Table 5.13 shows the selected percentile points for speed of performance.

Table 5.13: Selected centile points for time taken to complete the MASH form board from distribution of the reference group.

Seconds	Percentile point
73	5
71	10
60	15
44	50



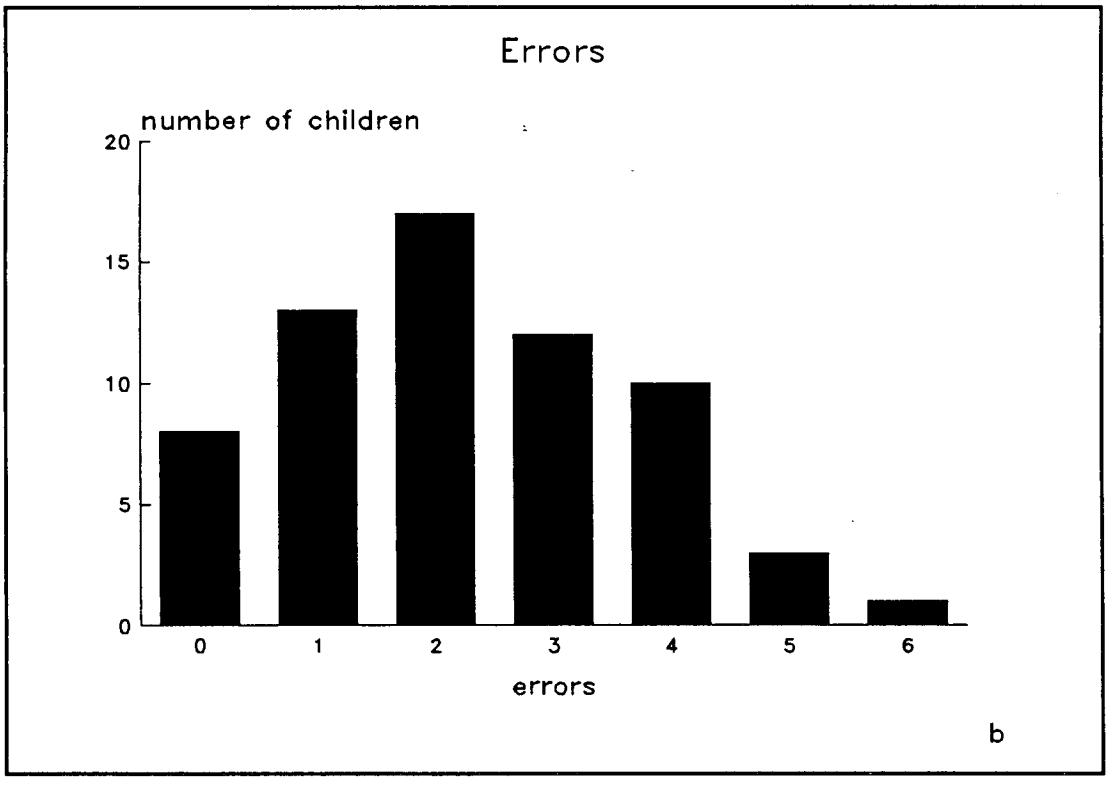


Figure 5.9: Distribution of time taken to complete (a) and number of errors made (b) on the MASH form board for the reference group.

Experimental manipulation of orientation of shape

In an attempt to increase the task demands, the orientation of the shapes was changed as they were displayed next to the board to examine the ability of the child to 1) find the correct hole and 2) to manipulate the shapes in such a way that they fit into the cavities.

Assessment description and procedure

This experimental manipulation led to a slightly different procedure in which the task was divided in three parts. Firstly, four shapes (the 2 stars and crosses) were presented in their 'normal' orientation (i.e. corresponding to that of the cavity). This was followed by the presentation of four other shapes (the 2 diamonds and symmetrical triangles) in a 'rotated' orientation, either 45, 90 or 120 degrees pivoted with respect to the orientation of the cavity. Finally, the last four shapes (the 2 houses and asymmetrical triangles) were displayed in a mirror imaged (along the vertical axe) or so–called 'turned' orientation relative to the orientation of the cavity. These 3 groups of shapes were successively presented in a standard fixed format with a short pause between each. Figure 5.10 shows the three different groups of shapes and the way they were presented to each child. Again, the children were instructed to insert each set of shapes as quickly as they could. For those children assessed at the Institute of Education a video tape was made of their performance on this task.

Normative data

Subjects

The same reference group as previously described were required to insert the shapes of the MASH form board under these conditions.

Results

Figure 5.11 shows the distribution of seconds it took the children to insert the shapes in the 'normal', 'rotated' and 'turned' orientation conditions. Median times to complete were 9.5 seconds (range=6–36), 18 seconds (range=7–70) and 48 seconds (range=16–200), respectively. Table 5.14 summarizes selected percentile points for each of the conditions.

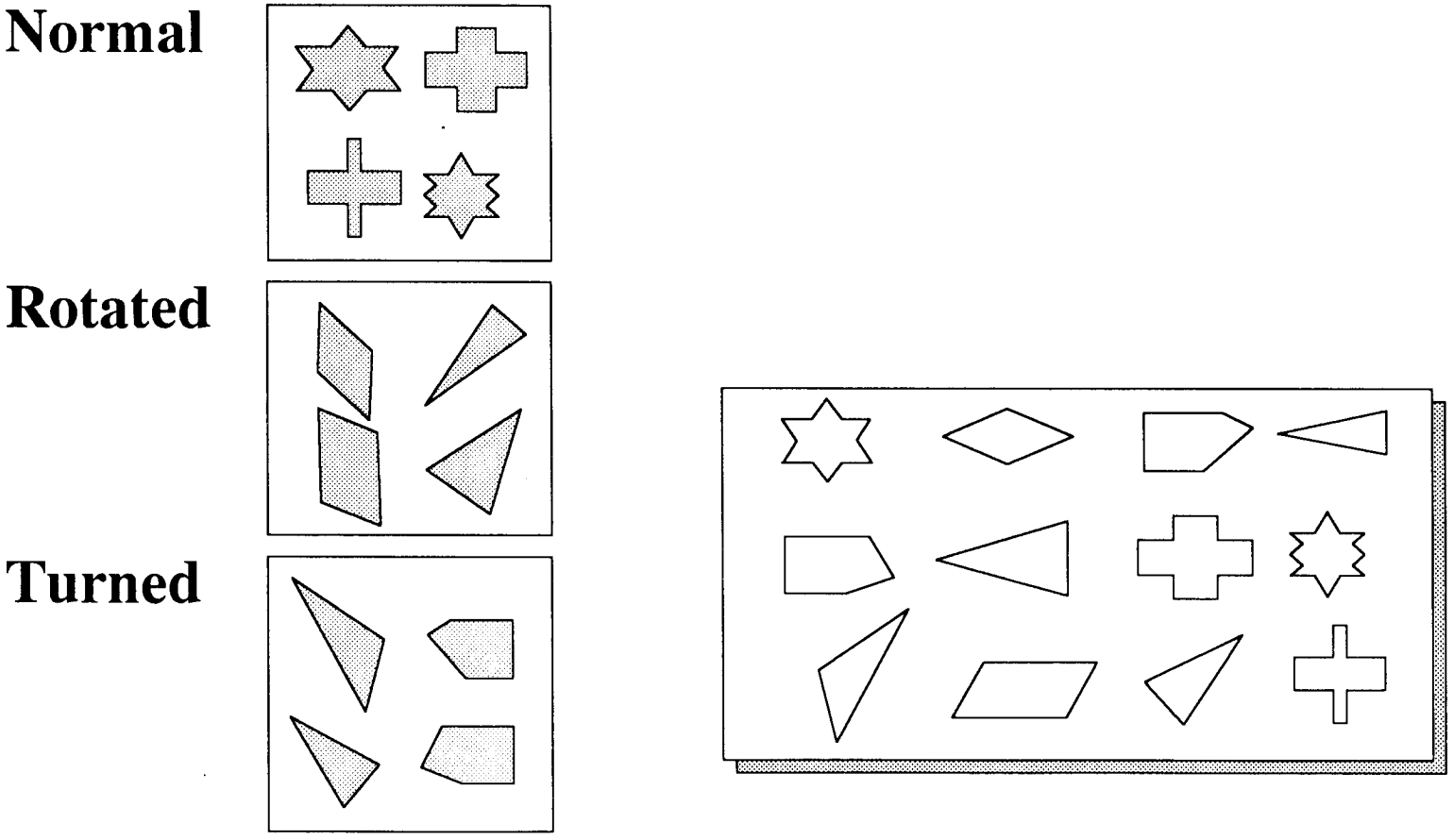


Figure 5.10: Orientation of shapes in the normal, rotated and turned conditions (left-hand side) and the MASH form board (right-hand side).

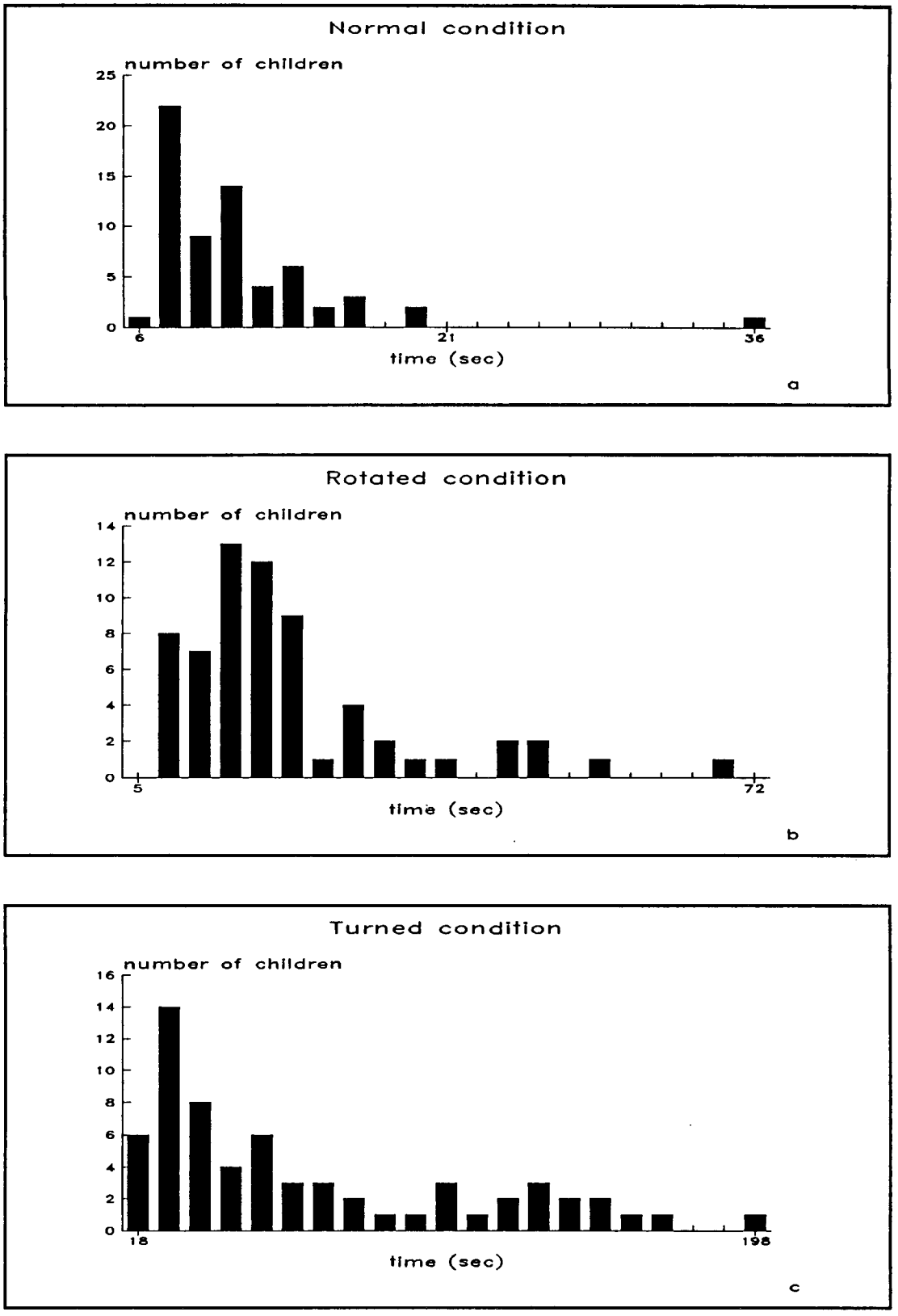


Figure 5.11: Distribution of time taken to insert shapes of MASH form board in the normal (a), rotated (b) and turned (c) condition for the reference group.

Table 5.14: Selected centile points for time to insert shapes of the MASH form board in three conditions from distribution of the reference group.

Seconds			Percentile point
Normal	Rotated	Turned	
16	48	155	5
15	40	142	10
13	31	127	15
9	17	46	50

Figure 5.12 shows the distributions of errors made in the various conditions. The median number of errors was 0 (range=0–2) for the 'normal' orientation group of shapes, 1 (range=0–6) for the 'rotated' group of shapes, and 1 (range=0–4) for the 'turned' group of shapes.

Reliability

Inter–observer reliability for number and type of errors when all 12 shapes were inserted at the same time and in the three orientation conditions was examined. The performance of 20 randomly selected prematurely born children was scored by a second observer (RS) from the video tapes. They were the same children as reported on in the reliability section of the Griffiths form board.

In the case of inserting all twelve shapes, the percentage of agreement between the two observers in terms of errors observed was 91%. The percentage of agreement in observing the number of errors made while inserting the groups of shapes in the three orientation conditions was of similar magnitude ranging from 93% (group 1), 94% (group 2) to 89% (group 3).

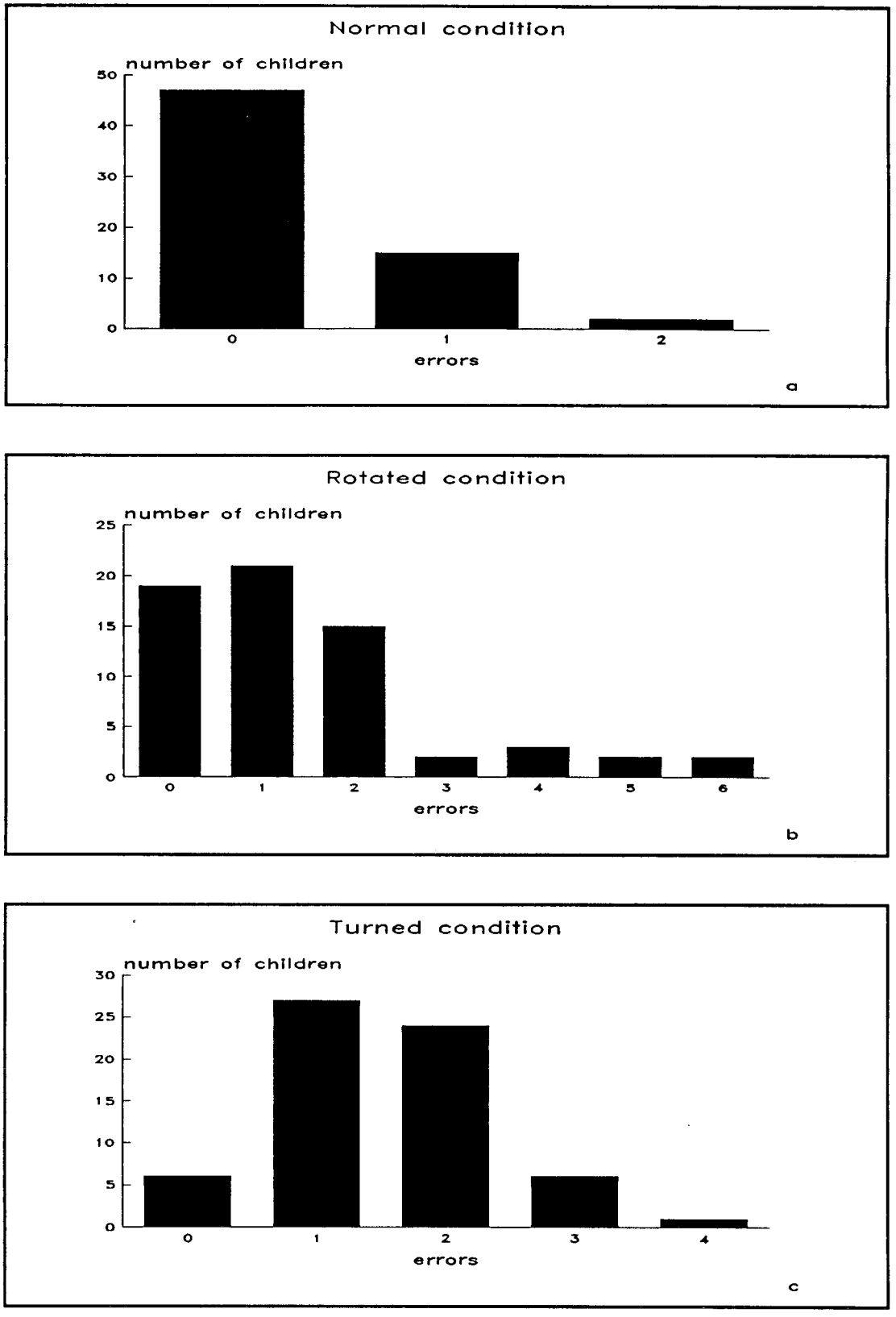


Figure 5.12: Distribution of errors made on the MASH form board in the normal (a), rotated (b) and turned (c) conditions for the reference group.

Constructional skills VI: Griffiths block design

Traditionally, the most frequent used way of investigating constructional skills is by means of a block design task. In this study we chose to administer the block design task described by Griffiths (1967). Although many other assessments of general cognitive ability such as the Wechsler Preschool and Primary School Intelligence test (WPPSI) and the British Ability Scales (BAS) include age-appropriate block design items, the Griffiths' version was chosen since we also used the form board task of the same author as a different measure of constructional ability.

Assessment description and procedure

The Griffiths block design task consists of 9 blocks. There are 3 red, 3 yellow and 3 blue blocks whose sides all have the same colour. In the present study the children were asked to complete 3 out of the 5 possible designs, i.e. design II, III, and V. Design I was used as a practice trial, while design IV was omitted because it only slightly differs from design III and was thought not to reveal any additional information. Figure 5.13 shows the designs used in this study. Children were asked to reproduce each design as quickly as possible.

Data recorded/obtained

Time taken to complete each design was recorded. The manual of the Griffiths Mental Development Scales (1967) describes the maximum time children of 6 years of age are expected to take to complete each design. Pattern II is actually not administered to this age group. However, 5-year-olds are expected to complete this design in 40 seconds, while 7-year-olds are allowed to take 20 seconds. In the absence of norms we, therefore, decided to take 30 seconds as an arbitrary cut-off point for 6-year-olds. Design III may take up to 60 seconds to complete, and design V should be completed in 40 seconds. In addition to recording time, a pass/fail score was given depending on whether or not the child managed to put the blocks together according to the design (irrespective of time taken).

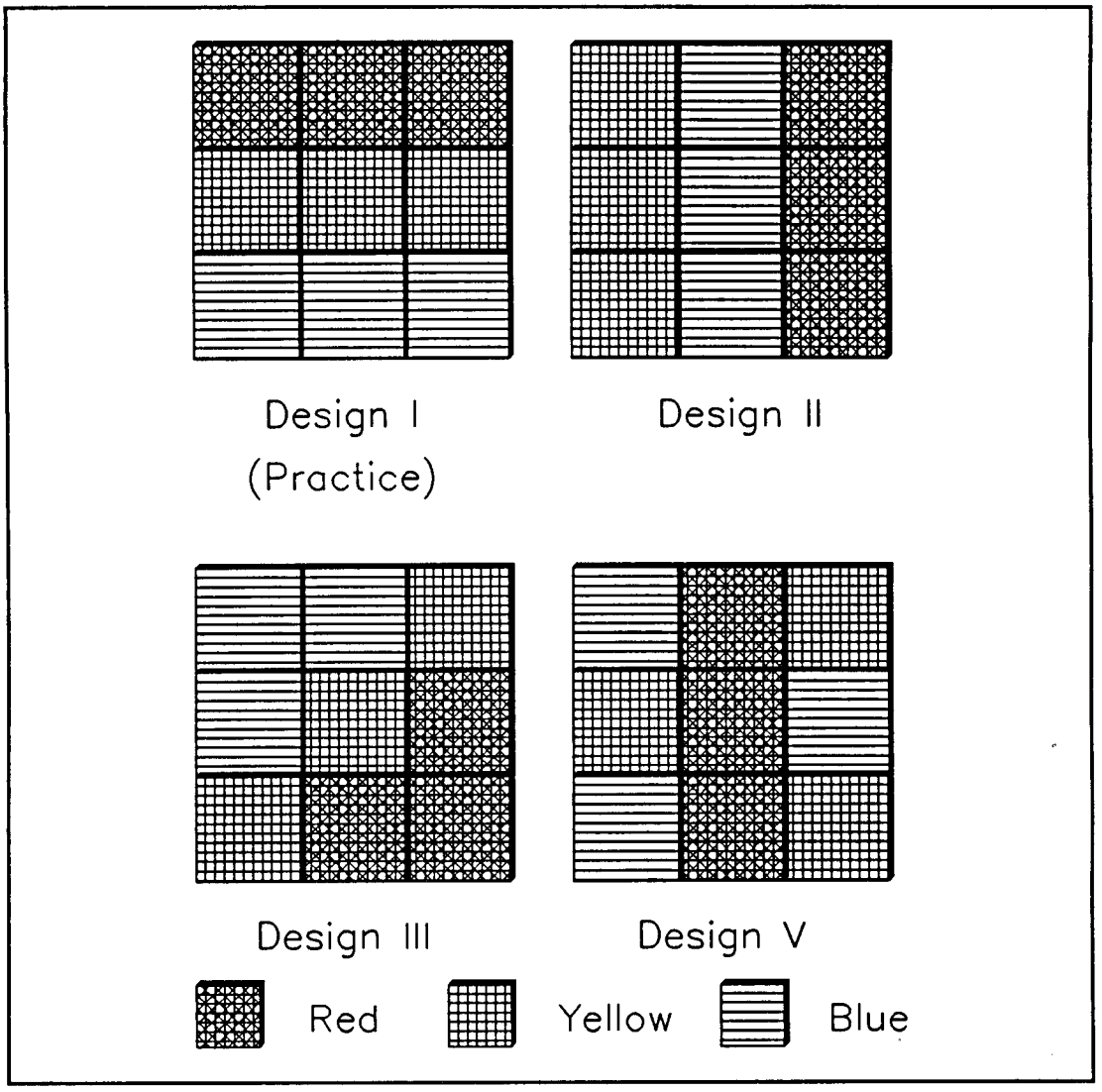


Figure 5.13: Four designs from the Griffiths block design task.

Teachers' observations of perceptual-motor competence

When the perceptuo-motor assessments were administered the examiners were not aware of the details of the neonatal status of the child and this information was only accessed when all the data had been collected. It could be argued, however, that because of our knowledge of the research questions being asked we may have been biased in our evaluation of the children. Observations of independent observers, in this case teachers, was therefore thought to be important for two reasons. First, such opinion would represent an almost totally unbiased view. Although a teacher may have been informed by the parent that the child was born prematurely, she or he was much less likely to be aware

of complications that may have occurred around the time of birth, including the presence or absence of a brain lesion. Second, their observations could act as an external validation of the individually administered assessments like Touwen's neurological Examination or the Movement ABC Test.

Inspired by the 1988 Education Act and the advent of the National Curriculum, Sugden and Sugden (1990) produced a tool for teachers helping them to assess and manage children with movement difficulties. This Checklist, which is the most comprehensive available at present, forms part of the Movement Assessment Battery for Children and was chosen to become part of our battery.

Assessment description and procedure

The sections included in the Checklist are based upon the notion that an individual performs a task in a contextual setting: both the individual and the state of the environment are taken into account while evaluating a range of 'ecologically valid' movement skills. The Checklist consists of 2 sections: one in which the teacher rates the child's competence on 40 items involving physical activities in the classroom or on the playground, and another section comprising 10 items on the child's behaviour towards physical activity. Using parents as intermediaries, teachers were asked to complete the Checklist and send it back to us. The content of the Checklist is given in Table 5.15.

Data recorded/obtained

Each question in the Checklist can be answered on a four point scale ranging from 0 (child is good at the activity described or child rarely shows the described behaviour) to 3 (child is not close to achieving the activity describes or child often shows the behaviour described). For each category a score is obtained by simply adding the score given by the teacher for each item within the category. The higher the score, the less competent is the child in the eyes of the teacher. A total score can be obtained by adding category one, two, three and four. The fifth category on behaviour of the child is not taken into account for the purpose of evaluating the child's movement competence.

Table 5.15: Content of Movement Assessment Battery for Children Checklist.

Section 1: Child stationary/Environment stable
The child can: 1.Put on and take of articles of clothing without assistance (shirt, sweater, skirt, socks) 2.Tie shoelaces, buckle belt, fasten a zipper/buttons 3.Demonstrate competence in personal hygiene (was hands, brush/comb hair) 4.Demonstrate good posture when sitting or standing (at desk/table, on a chair, in line) 5.Stand on one leg in stable position 6.Hold instruments (scissors, pencil/pen/crayon/paintbrushes) using proper tension and grasp 7.Demonstrate precision/accuracy by cutting, drawing, tracing between lines, around/over a designated pattern 8.Accurately and legibly form letters, numbers and basic geometric shapes 9.Pick up small objects (blocks, beads, puzzle pieces) 10.Use the items in No.9 to complete appropriate task (build a tower, thread together a series of beads, put together a jigsaw) 11.Turn the pages of a book, hand out individual sheets from a stack of paper 12.Recognize own bode parts and differentiate between left and right
Section 2: Child moving/Environment stable
1.Walk around the classroom/school avoiding a collision with any stationary objects/persons 2.Carry objects around the classroom, school or playground avoiding a collision with stationary objects/persons 3.Run and then stop to avoid stationary objects/persons 4.Skip or gallop a distance of 15 feet (4.5 m) 5.Hop in a controlled manner using preferred and non-preferred foot 6.Jump across/over obstacles that might be found in the play environment (blocks, low hurdles, ropes) 7.Execute an underarm throw using a small ball or bean bag into a container or to another child while running or walking 8.Execute a one-hand overarm throw using a small ball or bean bag into a container or to another child while running or walking 9.Use fixed playground/gymnasium apparatus such as climbing frame, slide and/or low balance beam 10.Manoeuvre through/around an obstacle course appropriate to age and ability 11.Run/walk to kick a large stationary ball, using preferred foot rather than shin or leg 12.Demonstrate an understanding of directional commands by moving forward/backward; over/under; around/through; in/out; to the left/right

Continued .....

Section 3: Child stationary/Environment changing

1.Pass objects from one child to the next (pass the parcel, giving and receiving books and paper)
2.Manipulate/construct objects in collaboration with another child (build a tower, pull bread dough, stretch fabric/paper)
3.Intercept and stop a moving object (toy train or car, ball) as it approaches/enters the field of reach
4.Kick a large approaching ball rolling at moderate speed, using the foot rather than shin or lower leg
5.Catch a large approaching bouncing ball using two hands
6.Catch a small approaching bouncing ball using one hand
7.Catch a large approaching ball in flight using two hands
8.Catch a small approaching ball in flight using one hand
9.Hit/strike a moving ball using a bat, racket or stick
10.Turn a skipping rope with sufficient force and accuracy to allow another child to enter the moving rope
11.Continually bounce a large playground ball while standing still
12.Keep time to a musical beat by clapping hands

Section 4: Child moving/Environment changing

1.Move around the classroom/school/playground while avoiding collision with other moving persons
2.Use non-stationary playground/gymnasium apparatus such as swings unassisted
3.Ride moving vehicles such as pedal cars, tricycles, scooters and bikes
4.Push/pull wheeled vehicles such as prams, wagons, library and mat trolleys
5.Participate in chasing games (tag, Mr Wolf)
6.Run to catch an approaching ball
7.Run to kick an approaching ball
8.Run to hit/strike an approaching ball with bat, racket or stick
9.Move to enter a turning skipping rope
10.Move around keeping control of a bouncing ball
11.Use skills of striking, kicking, catching and/or throwing to participate in a team game
12.Move in a variety of directions, styles and speeds while keeping time to a musical beat

Section 5: Behaviors related to physical activity

1.Overactive(squirms/fidgets;moves constantly when listening to instructions;fiddles with clothes)
2.Passive(hard to interest;requires much encouragement to participate;seems to make little effort)
3.Timid (fearful of activities like jumping/climbing;does not want to move fast;complains about the possibility of getting hurt; constantly asks for assistance)
4.Tense (appears nervous,trembles; fumbles with small objects; flustered in stressful situation)
5.Impulsive (starts before instructions/demonstrations are complete; impatient of detail)
6.Distractible (looks around; interrupts instructions with irrelevant questions;responds to noises/movement outside the room;needs additional information to complete task/activity)
7.Disorganised/confused (difficulty in planning a sequence of movements;forgets what to do next in middle of sequence;appears lost)
8.Overestimates own ability (attempts too many things at one time;tries to change tasks to make them more difficult; tries to do things too fast)
9.Underestimates own ability (says tasks are too difficult;makes excuses for not doing well before beginning;always takes the 'easy option')
10.Lacks persistence (gives up quickly; easily frustrated; daydreams)
11.Upset by failure
12.Appears to get no pleasure form success
13.Other

Normative data

The Movement ABC Checklist has been standardized on a cohort of children ranging from 6 years to 9 years of age. The authors chose to collapse the data of the 6- and 7-year-olds and the 8- and 9-year-olds to form two groups and have reported the data accordingly. However, for the purpose of the present project we felt that we needed separate norms for 6-year-olds as our entire cohort consists of children of this age. Therefore, the authors of the Checklist gave permission to perform separate analysis on a sub-group of their standardization cohort.

Subjects

The standardization cohort of the Movement Assessment Battery for Children Checklist included a random selection of 56 6-year-old children (27 boys, 29 girls) from 25 schools ranging from those in the inner city to those in the country within a clearly defined geographical area of the United Kingdom. Their ages ranged from 72 months to 83 months. Mean age was 80.2 months (SD=2.5). Each child's movement competence was assessed by their own teacher.

Results

Table 5.16 summarizes the mean item score for each Section separately as well as the total score (Section 1 to 4) for the whole group of children.

Table 5.16: Mean (SD) scores per section of the Movement Assessment Battery for Children Checklist for the reference group.

Section	No. of questions	Mean (SD)
1	13	7.96 (7.34)
2	13	9.11 (8.14)
3	10	12.11 (6.42)
4	10	9.25 (6.17)
Total 1 to 4	46	38.30 (25.20)
5	9	4.32 (5.83)

A oneway mixed measures ANOVA revealed a main effect of sex (F= 5.68, df=1,53; p<.05). In the eyes of the teachers boys were less competent at the tasks described in the checklist than girls. Furthermore, there was a main effect of section (F=13.84, df=3,159; p<.0001). A Newman-Keuls post-hoc test revealed that performance on section 3 differed from all the other sections. Section 1, 2, and 4 did not differ from each other. There was no interaction between sex and section.

Furthermore, Table 5.17 gives the percentile points for the mean total item score. The bottom 15% of the children obtained a score of 1.46 or more.

Table 5.17: Percentile points of mean total item score (section 1 to 4) from distribution of the reference group.

Mean total item score	Percentile point
2.07	5
1.62	10
1.46	15
0.73	50

5.4.2 Vision and visual discrimination

The assessment of vision was limited to measures of acuity and stereopsis. To assess visual perception we focused exclusively on tasks which we thought might be relevant to performance on our form board tasks. Thus the assessment of visual discrimination was confined to the use of 2 or 3 dimensional stimuli (i.e. patterns drawn on paper or 3 dimensional shapes).

Vision I: Acuity

Among the studies discussed in Chapter 2, few investigated the vision of school aged premature children (e.g. Fawer & Calame, 1991). Therefore, we included this measure to establish both major and minor visual defects in children born prematurely.

Assessment description and procedure

To provide a measure of near and distant visual acuity, the Sonksen–Silver Acuity System (1988) was administered. Near visual acuity was tested at a distance of 30 cm. Because of the size of the assessment room, children were assessed for distant visual acuity at a distance of 3 metres as suggested in the instruction manual.

Data recorded/obtained

Both single optotype and linear reading scores were assessed.

Vision II: Stereoscopic vision

Assessment procedure and procedure

In order to perceive depth and distance adequately we need stereoscopic vision. To measure this aspect of vision the Stereo Test (Stereo Optical Company, 1988) was administered. The test contains three items: a fly (gross stereopsis), circle patterns (a finely graded sequence for critical testing) and a series of animals (to facilitate testing of younger children).

Data recorded/obtained

For this test a pass or fail criterion was used.

Visual discrimination I: Matching Letter–Like Forms (BAS)

The first visual discrimination task to be administered is the Matching Letter–Like Forms Scale which is part of the earlier described BAS (Elliott et al., 1983). Apart from the advantage that the assessment is norm–referenced it was also chosen because performance on this Scale is easily comparable to other Scales of the BAS and, therefore, consistency of performance across different areas of development could be evaluated.

Assessment description and procedure

The Scale consists of a number of asymmetric, letter–like forms, consisting of straight lines and curves, many of which are very similar to letters of our alphabet or the Greek alphabet. For each item, a standard figure is presented on the upper page of a booklet, and on the lower page this standard is included among five other transformations, the

transformations being reversal, 180 deg. rotation, 180 deg. rotation and reversal, 45 deg. rotation, and 315 deg. rotation. The child is required to look at the standard figure and then to select one of those from the display of six figures below which is identical to the standard figure. There are 15 items for the child to identify.

Data recorded/obtained

A correct response is scored as 1 and an incorrect response is scored as 0. Results were expressed in the form of a T-score.

Visual discrimination II: triangle test

The second measure of visual perception was recently applied in two studies concerned with visuo-spatial skills in children with perceptuo-motor problems (Lord & Hulme, 1988; Henderson et al., submitted). However, after having tested a number of premature children in the present study we decided to develop a computer version of this task since it was obvious that these first few children found it difficult to sustain their concentration if the original procedure was used (i.e. a card version). Also, as children nowadays are familiar with computers we thought it might increase their motivation to complete the task.

Assessment description and procedure

The original task consists of 32 pairs of triangles: 16 'same' and 16 'different'. Pairs of triangles were drawn in single outline in black ink against a white background on 15 x 26 cm cards, separated by a black transverse midline. In 'same' pairs the two triangles are equilateral, with sides 70 mm long. In 'different' pairs the dimension of the upper triangle is held constant at 70 mm. In the lower triangle the length of the two sides is held constant at 70 mm, while the length of the base ranges from 46 to 94 mm in 3 mm steps (excluding 70 mm). The cards were presented according to a fixed schedule in which they followed each other in random order. The task for the child was to say for each card whether the two stimuli were the same or different.

The procedure for the computer version of the task was exactly the same with the exception, of course, that instead of looking at pairs of triangles on cards the children now

looked at pairs of triangles on the screen and pressed either of two buttons to indicate whether or not they thought the triangles were the same or different.

Data recorded/obtained

Performance on this task was evaluated by converting hits (correct 'different' responses) and false alarms (incorrect 'different' responses) into discrimination values (*d'*) which represent the difference between the probabilities of hits and false alarms occurring and are expressed in standard deviation units (see Lord & Hulme, 1988).

Pilot study

In order to check whether it was justified to replace the original card version with the newly developed computer version a small pilot study was conducted.

Subjects

Twenty-nine prematurely born children completed both versions of the triangle test, i.e. the card and computer version. All children completed the card version first (approximately halfway during the entire assessment), then other parts of the test-battery were completed and at the end of the entire assessment the computer version was administered. Although we admit that a randomized procedure would have been more appropriate, the fixed structure of the entire assessment procedure, however, did not allow this.

Results

Discrimination values were calculated for each child. A paired t-test showed that the difference in mean discrimination values of the card (1.67; SD=1.11) and computer version (1.45; SD= 1.33) did not differ significantly from each other (t=0.84, p>.05).

Reason for <u>not</u> incorporating triangle test data in this thesis

We collected data on the triangle test for approximately 70 premature children. However, after these it was decided to drop this item from the test-battery for the remainder of the cohort since it took a long time to administer and children appeared to find it too tedious which may affect reliability.

Visual discrimination III: matching the MASH form board shapes

In order to determine the relative contribution of visual perceptual problems to performance on the MASH form board (e.g. speed and accuracy of inserting the shapes in the cavities) it is essential to have an indication of whether the children are able to discriminate between the 12 shapes. We, therefore, decided to assess the ability to match each shape with the corresponding cavity.

Assessment description and procedure

Before the child had worked with the MASH form board, the base was placed in front of him without the shapes inserted. Then one of the twelve shapes was put on a white sheet of paper above the base by the experimenter. The child's attention was drawn to the cavities in the board by asking him to follow the finger of the examiner pointing out all the cavities in the base. The child was then asked to use his own finger to point towards the cavity in which he thought the shape should be inserted. After the child had completed one trial the shape was removed and replaced by a different one and the child was again asked to point to the cavity in which he thought the new shape belonged. The child had no physical contact with the shapes throughout the session. All children received the same order of presentation of shapes.

Data recorded/obtained

Pass or fail was recorded as well as the cavity to which the child pointed wrongly to in case of failure. Number of errors out of 12 was used as a score.

Normative data

As no norms were available for performance on this task, we set out to determine the range of scores obtained by a reference group.

Subjects

The same reference group of 6-year-olds who completed the Griffiths and MASH form boards were tested on their ability to visually match the shapes of the MASH form board.

Results

Table 5.18 shows the distribution of the total number of unsuccessful matches across the whole cohort. There were 6 children who were able to complete the task without any errors and the median number of unsuccessful matches (out of 12) was 3. Although not completely precise, the 15th percentile point on this distribution of total number of errors was set at 4 errors. The sensitivity of this visual matching task was good insofar as it yielded neither ceiling nor basement effects.

Table 5.18: Distribution of total errors when visually matching the shapes of the MASH form board for the reference group.

Errors	N	Cumulative percentage
0	6	9.4
1	3	14.1
2	18	42.2
3	14	64.1
4	12	82.8
5	6	92.2
6	4	98.4
7	1	100

5.4.3 Background information

In what follows, the assessment instruments used to measure general cognitive ability, reading, behaviour and self-concept will be presented. Due to financial and time constraints we were not able to collect normative data for any of these measures on a reference group ourselves. However, at the start of the present study the Thomas Coram Research Unit (part of the Institute of Education) had just finished a longitudinal study on the development of children receiving Day Care. At 6 years of age, these children were assessed on exactly the same measures as reported in this section and the TCRU made their data available to us.

TCRU cohort

The cohort consisted of 255 women and their first born children (130 boys, 125 girls) living in the greater London area. The children were selected according to the following criteria: 1) they were part of a two parent family 2) both parents had been in full-time employment up to the pregnancy 3) the women were all born in the British Isles and 4) where the mother intended to return to employment she intended to do so full-time and before the child was 9 months old.

The TCRU-group collected some information on the child's birth. One question, for example, asked the mother whether the child had been born prematurely and what the birthweight of the child had been. A closer examination of these data showed that 15 children out of the total cohort of 255, were born prematurely. Consequently, these children were omitted from the present analyses. Data of the remaining 240 fullterm children was used to compare to that of our own premature cohort. Exact ages of the children were not recorded, but all were tested within two months of their 6th birthday.

General cognitive ability

At present, the most widely used assessments of general cognitive functioning in young children are undoubtedly the Wechsler scales - either the WPPSI (Wechsler, 1967) or WISC-R (Wechsler, 1974). It was, therefore, an attractive proposition to use one of these two scales. However, the age of the children participating in this project (6 years) posed some problems as to which alternative to use. The WPPSI is specifically designed for use with children aged 4 years 0 months through 6 years 6 months, while the WISC-R is appropriate for children of ages 6 years 0 months through 16 years 11 months. This means that 6-year-old children are either at the top end of the WPPSI scales or the bottom end of the WISC-R. In both cases, this is a disadvantage in terms of reduced sensitivity of the items.

Since we were unable to find data which allowed us to make a well founded choice between the two scales we elected to use the recently introduced alternative, the British Ability Scales (BAS) (Elliott et al., 1983). This assessment has two advantages over the Wechsler Scales. First, it is suitable for administration to children aged 2 years 6 months

to 17 years 6 months. The assessment consists of 23 Scales measuring a range of cognitive functions and most of the Scales are suitable for a large range of ages. The second advantage lies in its psychometric properties. Each Scale has been developed and standardised separately so that it may be administered singly or in any combination with other Scales in the battery. The BAS, therefore, offers the possibility of administering any Scale of interest for a specific hypothesis and to relate performance on this Scale with any other Scale (i.e. consistency or inconsistency of performance). As with the Wechsler Scales, the BAS offers the possibility of calculating a short-form IQ.

Assessment description and procedure

The following Scales of the BAS were administered in our study:

Matrices: The Matrices Scale provides a measure of (non-verbal) reasoning ability. Initially, the child has to deduce the relationship between the figures in the cells of a matrix and then, on the basis of that analysis, produce an appropriate solution which he draws in a blank cell. The Scale consists of 28 items.

Similarities: The Similarities Scale provides a measure of verbal reasoning. In addition, the task involves verbal comprehension and the retention of verbal instructions. The child is given three words and is asked to name the class to which all the examples belong (e.g. examples=apple, strawberry, banana; class=fruits). There are 21 items in the Scale.

Digit Span: The Digit Span Scale provides a measure of immediate recall. Early items consist of sequences of 2 digits and this then gradually increases until the final items are 9 in length. There are 36 items in the Scale.

Naming Vocabulary: This Scale is intended to measure the vocabulary of children. The items require the child to recall a word from long-term memory. The first four items are related to objects in the testing room, and the remaining items arise from a booklet of coloured pictures of objects which the child is shown one at a time. There are 20 items in the Scale.

Data recorded/obtained

For all the Scales a correct response is scored 1 and an incorrect response 0. Performance on each of these Scales can be expressed as a T-score (mean=50; SD=10) and centile. The mean T-score of these four Scales was used to compute the short-form Intelligence Quotient for children between the ages of 5 years to 7 years 11 months (Elliott et al., 1983).

Normative data

TCRU cohort

Complete data on the Matrices, Similarities, Naming Vocabulary and Digit Span Scales was available for 215 children. Consequently, it was possible to calculate the short-form IQ estimate. Table 5.19 summarizes the mean T-scores (SD) and selected centile points on the Scales.

Table 5.19: Mean (SD) T-scores and percentile points on the British Ability Scales from the distribution of the reference group.

	SIQ	Mat	Sim	Voc	Dig	Read *
Mean (SD)	115 (13)	57 (11)	61 (9)	58 (10)	53 (9)	50 (14)
5th	93	47	47	42	40	10
10th	98	47	50	46	42	35
15th	100	47	53	46	44	39
50th	116	54	61	59	53	51

Legend: SIQ=Short-form IQ; Mat=Matrices; Sim=Similarities; Voc=Naming Vocabulary; Dig=Digit Span; Read=Word Reading; * see next paragraph on Word Reading

It is obvious from this Table that on the short-form IQ estimate this group deviated considerably from the notional mean of 100 (15) to which the BAS were standardized. Two recent studies involving low birthweight cohorts have found a similar upward drift in IQ scores among both index and control groups (Marlow et al., 1990; Astbury et al., 1987).

Reading

As described earlier, one of the overall objectives of the main study was to evaluate to what extent prematurely born children have adapted to the demands placed upon them by school. Although it would be desirable in this context to investigate the children's ability in all facets of their academic work, i.e. writing, number skills, reading and language skills, it was beyond the scope of this project to include all these measures. As a compromise we selected what we regard as one of the most important skills to be learned at school, namely reading.

As a measure of reading ability we chose to administer the Word Reading Scale, which is part of the BAS. The main reason for including this particular reading assessment was that, as described previously, performance on this Scale can be directly compared to performance on other Scales.

Assessment description and procedure

The Word Reading Scale consists of 105 single words increasing in difficulty. The child was asked to read aloud one word at a time.

Data recorded/obtained

T-scores and centile points were calculated.

Normative data

TCRU cohort

The 215 children were also tested on the Word Reading Scale. The distribution of their scores is summarised in Table 5.19.

Behaviour

Compared to physical, neurological and intellectual development, little attention has been paid to the emotional and social development of prematurely born children. It is only recent that questions of whether behaviour problems exist which affect the ability to adjust to the requirements of school, family and society are being asked (e.g. McCormick et al., 1992; Ross et al., 1990). In the present study we wished to include a measure which

might assess this.

Examples of behaviour measures that have recently been administered to groups of prematurely born children range from standardized measures such as the Behaviour Check List (Richman et al., 1982), to checklists compiled by the authors themselves (e.g. Hadders-Algra et al., 1988). Although many other standardized measures are available such as the Child Behaviour Check List by Achenbach & Edelbrock (1983) and the Bristol Social Adjustment Scale by Stott (1963), we chose to administer the Rutter Scales (1967) in our study. They were chosen because they are the most widely used in Great Britain (e.g. Marlow et al., 1990; Noble-Jamieson et al., 1982; Stewart et al., 1989). Another reason for choosing the Rutter Scales is that they are short, simple questionnaires which will hopefully increase the return-rate (especially by teachers). Furthermore, because of the overlap in the Scales we would be able to compare the child's behaviour at home with that at school.

Assessment description and procedure

Both parents and teachers were asked to complete the appropriate Rutter Scale, i.e. the Rutter Scale for Parents (Scale A (2); 1965) or the Rutter Scale for Teachers (Scale B (2); 1967). The Parent Scale consists of 31 brief statements, for example, "Cannot settle to anything for more than a few moments", and parents are asked to indicate to which extent the statement applies to the child rated 0-2 according to severity. The Teacher Scale consists of 26 statements and the same scoring system is used.

Data recorded/obtained

In the present study we analyzed the data generated by these Scales on the basis of the total scores given by the parents and teachers.

Normative data

TCRU cohort

The parents of 204 fullterm children and 192 teachers completed the appropriate Rutter Scale. Table 5.20 summarizes these data. The median total score given by parents was 12 (range=1-45) and 4 (range=0-35) by teachers.

Table 5.20: Median (range) and percentile points for scores on the Rutter Scale for parents and teachers of the reference group.

	Parents (n=204)	Teachers (n=192)
Median (range)	12 (1–45)	4 (0–35)
5th	27	15
10th	24	12
15th	21	10
50th	12	3

Self–concept

Clinicians frequently comment on the fact that premature infants in general are emotionally immature (e.g. Drillien, 1967) yet it is very rare for follow up studies, like the present one, to provide data on how the children perceive themselves and even more unusual to take account of the interaction between self–concept and performance in various domains. In a study looking at the strengths and weaknesses of a specific population of children, however, it is interesting to consider how the children themselves feel about this. It was, therefore, decided to include such a measure.

The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children, developed by Harter and Pike (1983; 1984) provides a measure of children's self–concept and is a well established assessment. From the research these authors have done it is known that younger children are not able to make meaningful judgements about their global self–worth as a person until approximately the age of 8. However, before this time they are able to evaluate their performance in particular domains of their lives. Items tapping specific abilities, for example, doing well in sports or in one's school work, have meaning, whereas items describing the degree to which one likes oneself as a person or is happy being the way they are do not have meaning for the young child (Harter, 1986).

Assessment description and procedure

The Scale consists of 24 pictures which are designed to elicit the child's view of him/herself in the following four domains: cognitive competence, physical competence, peer acceptance and maternal acceptance. The child is asked to give his opinion on 6 different items for each domain. There are separate booklets for boys and girls. The response of the child is scored on a four point scale. The higher the score, the more competent/accepted the child feels on the item.

Data recorded/obtained

The mean score on the six items is taken as the child's overall perception of competence or acceptance in a particular domain. It is, therefore, possible to check whether the children provide realistic or unrealistic perceptions of themselves by investigating how well performance on an assessment such as the BAS correlates with scores on specific domains such as cognitive competence. Alternatively, differences between domains may be useful in predicting behaviours, motivations and/or emotional reactions of interest.

Normative data

TCRU cohort

The TCRU collected self-concept data on 214 fullterm children. The median scores, range and selected percentile points on each of the four components of the Scale are summarized in Table 5.21.

Table 5.21: Median (range) and percentile points for scores on the four components of the self-concept Scale of the reference group.

	Cognitive	Peer	Physical	Maternal
Median (range)	3.33 (1.33–4.00)	3.17 (1.67–4.00)	3.17 (1.50–4.00)	3.00 (1.40–4.00)
5th	2.17	1.67	2.33	2.00
10th	2.50	2.17	2.50	2.20
15th	2.83	2.33	2.67	2.40
50th	3.17	3.00	3.17	2.80

Demographic variables and history

In the present project, a parent interview was thought to be the best way of obtaining information regarding SES. Having examined similar questionnaires used in other studies (The Scottish Low Birthweight Study Group and The Groningen Perinatal Project) the series of questions listed in Table 5.22 was compiled.

Assessment description and procedure

The questionnaire was divided into several sections: the child at home, the house the child lives in, health of the child since leaving the neonatal unit, whether the child has been to nursery between 2 and 5 years of age, type of school the child is attending at the moment and whether or not any special assistance is given at school. Finally, the SES of the parents is established. In this last section the occupation of the parents, age of leaving school and last schooling received is recorded. The paediatrician (LMSD) interviewed the parents while the child was assessed in the room next door.

Data recorded/obtained

Although we are aware it is not the most ideal measure of SES, it was decided to take mother's educational level as the best estimate of SES.

Table 5.22: Items from the questionnaire on demographic variables and medical history.

The child at home
1 What is the place of the child within the family
2 Is the child is adopted or fostered
3 Who generally takes care of the child
The house
4 What kind of house do you live in
5 Which floor(s) do you occupy
6 How many rooms are there
7 Do you have a garden available for the child to play in
Health of the child
8 Has the child been readmitted to hospital after coming home from the neonatal unit
9 Has the child had treatment from the G.P. for illnesses
10 Does the child have convulsions
11 Is the child taking any drugs or medication just now
12 Does the child have any aids
School
13 When the child was between 0 and 2 years of age did (s)he spent time with, or at a childminder, nanny or nursery
14 When the child was between 2 and 5 years of age did (s)he spent time with, or at a playgroup, nursery or other
15 Is the child attending a state or private school
16 Has the child had any extra help in school
17 Has the child had any help out of school
18 Was, or is, there any help you would like to have (had)
19 Can you tell us what the child likes to do 1) indoors: drawing, reading books, Lego or other construction-toys, jigsaws or other? 2) outdoors: ball games, climbing trees or apparatus, cycling or other
20 How would you rate your child's reading ability
21 Is there anything else you would like us to know about the child which we have forgot to ask you

continued ....

SES

1 How many people live together with the child in the house
2 Does this include: both natural parents, 2-parent family but one natural parent, single parent, other family members or other adults
3 What is the occupation of the father
4 Is he employed full time, part time, unemployed, etc.
5 When did he leave school
6 What was the last schooling he had
7 What was the mother's occupation before she was married
8 Does the mother have a job at present
9 Is she employed full time, part time, unemployed, etc.
10 When did the mother leave school
11 What was the last schooling she had

5.5 Summary

In this Chapter a detailed outline of our highly selected cohort of prematurely born children has been given. Again, it should be stressed that our aim was to study only those children whose early neurological status was well documented and that we did not attempt to study all children born in a particular region or hospital. The final cohort consisted of 183 children. Throughout the study we have tried to ensure (within reasonable limits) that both examiners were blind as to the neonatal status of the child.

In the present study we evaluated performance of the children on a comprehensive range of perceptuo-motor assessments and measures of cognitive ability, behaviour and self-concept. The focus of this thesis will be on performance on the perceptuo-motor assessments. In contrast to most other follow up studies, the range and specificity of the items in this category are extensive. In addition to observing the children ourselves, independent opinions on the children's perceptuo-motor competence was sought from teachers.

Finally, instead of relying completely on normative data provided by standardised assessments to evaluate performance of prematurely born children, we set out to collect local norms (and in the case of Touwen's neurological Examination investigated the reliability and validity) or obtain norms from cohorts of children recently tested.

CHAPTER 6

Premature children at 6 years – a global view of perceptuo-motor competence

6.1 Introduction

6.2 Overview of performance on the neurological Examination, perceptuo-motor assessments and other measures

6.3 Neonatal and demographic variables: their relation to neurological status and perceptuo-motor competence

6.4 Prevalence of children with perceptuo-motor problems

6.5 Discussion

6.1 Introduction

The first objective the present Chapter is to provide an overview of the differences between the highly selected group of prematurely born children that make up the present cohort and the reference children selected from a normal school population. This will allow the findings of the present investigation to be compared other follow up studies involving similar children.

The second objective is to focus on the relationships between selected neonatal or demographic variables, neurological status and perceptuo-motor performance within the cohort. Birthweight and gestational age have been the principal selection criteria for follow up studies on children born 'at risk' and these two variables are also considered in this Chapter. In addition, although variables such as gender and ethnic origin have been investigated in relation to perceptuo-motor development in normal children, relatively little is known about whether these factors interact with prematurity in any way. From a recent literature review by Ornstein et al. (1991) it was noted that only 28% of VLBW follow up studies addressed the issue of gender as an independent variable affecting outcome.

Finally, a brief sketch is provided of the children whose performance lags behind that of their age matched peers in the perceptuo-motor domain. In this section, children who could clearly be classified as having a central motor deficit are described separately from the more nebulous group, often labelled 'clumsy'. Then, identification of the latter group is described together with the range and severity of their associated difficulties.

Subjects

The combined outcome of 172 children is reported in this Chapter. This includes the 7 children with partial assessments but excludes the 11 severely handicapped children whom we did not examine at 6 years of age.

Data analyses

For those data which did not meet parametric assumptions median scores were calculated, otherwise mean scores are reported. Nonparametric (Mann-Whitney U or Kruskal-Wallis

oneway ANOVA) and parametric (oneway ANOVA) univariate tests of significance are reported as appropriate to identify differences between the premature and reference groups. Due to the large number of comparisons, the probability level was set at .01. Post-hoc analysis following the Kruskal-Wallis test consisted of the Multiple Comparisons Between Treatments procedure as described by Siegel and Castellan (1988), while the Student Newman-Keuls test was applied following oneway ANOVAs. For the post-hoc analyses the alpha level was set at .05.

6.2 Overview of performance on the neurological Examination, perceptuo-motor assessments and other measures

This overview focuses on the standardised assessments for which normative data were available, i.e. Touwen's neurological Examination, the Movement ABC Test and Checklist, the Developmental Test of Visual-Motor Integration, and the form board task of the Griffiths Mental Development Scales. In addition, outcome on the BAS, Rutter behaviour questionnaire and self-concept scale will be reported here.

Differences between premature and reference children

In Table 6.1, a comparison between performance of the premature and the reference groups on the formally administered neurological and perceptuo-motor assessments is provided.

All four assessments discriminated between the two groups. The prematurely born children showed significantly more neurological signs, were less proficient in executing simple motor tasks, had more difficulty correctly copying geometric shapes and were slower in completing the form board. However, as can be seen from the overlap in the ranges of the scores, some of the children in the reference groups performed as poorly as the least proficient premature children. Conversely, some premature children were as able as the reference children.

Table 6.1: Neurological status and perceptuo-motor competence of the premature and reference groups (median, range, N).

	Premature	Reference	p^
Touwen's Examination *total optimality score*	38 0-46 172	40.5 31-46 64	***
Movement ABC Test *total score*	5.5 0-40 172	2 0-26 88	****
Visual-Motor Integration *standard score*	8 0-15 172	9 4-15 60	**
Griffiths form board *time to complete (sec)*	35 22-145 172	32 20-94 64	***

^ Mann-Whitney U test; ** p<.01; *** p<.001; **** p<.0001

Prevalence of central motor deficit

Of the 172 children examined at 6 years of age, 15 (9%) were classified as having a central motor deficit of whom one child had a severe visual impairment [1]. Among the children with a central motor deficit, 4 had spastic diplegia, 6 children were hemiplegic, 3 children were classified as having di-/quadriplegia, one child as a hemi-/triplegia, and finally one girl had quadriplegia. Five children could not walk independently; 2 were wheelchair bound and another 3 used walking aids.

Neurological optimality

The finding that premature children show more minor neurological signs than their randomly selected peers was in agreement with other studies which have used the same neurological Examination at school age (Hadders-Algra et al., 1988; Marlow et al., 1989; Noble-Jamieson et al., 1982). However, the outcome on this Examination has only twice been reported in terms of the objective scores (Largo et al., 1989; 1990a), instead, most

[1] *When the 11 children we did not examine at 6 years are included the total number of children with a central motor deficit rose to 26 (14%).*

studies preferred to report outcome in qualitative terms such as, for example, 'normal', 'abnormal' or 'suspect'.

In the present study neurological outcome was judged not only on the total neurological optimality score but also a more detailed analysis of cluster scores was performed. The results of this latter analysis showed that out of the 9 clusters in Touwen's Examination, premature children in the present study showed more minor neurological signs in 5 clusters (Table 6.2).

Table 6.2: Neurological optimality scores of the premature and reference groups on the clusters of Touwen's Examination (median, range).

Cluster	items	Premature (n=172)	Reference (n=64)	p^
Sensorimotor apparatus	9	9 (0–9)	9 (7–9)	****
Posture	7	6 (0–7)	6 (1–7)	ns
Balance of trunk	4	3 (0–4)	3 (2–4)	ns
Coord. of extremities	5	3 (0–5)	4 (0–5)	***
Fine manipulation	3	3 (0–3)	3 (1–3)	**
Dyskinesia	5	5 (0–5)	5 (2–5)	ns
Gross motor functions	6	4 (0–6)	6 (3–6)	****
Quality of motility	3	3 (0–3)	3 (0–3)	ns
Associated movements	4	4 (0–4)	4 (1–4)	****
Total optimality	46	38 (0–46)	40.5 (31–46)	***

^ Mann–Whitney U test; ** p<.01; *** p<.001; **** p<.0001

They were 'sensorimotor apparatus', 'co-ordination of extremities', 'fine manipulation', 'gross motor functions' and 'associated movements'. These findings are in close agreement with those of the earlier mentioned study by Largo et al. (1989) who reported small but significant differences in scores on the 'co-ordination of extremities', 'fine manipulative ability' and 'associated movements' between AGA preterm and fullterm boys at 6 years of age. In addition, they found AGA preterm boys and girls to perform more poorly on the items of the 'quality of motility' cluster.

Although in recent years the reliability of some selected neurological 'soft signs' has been established (Stokman et al., 1986) most neurodevelopmental tests still do not meet the standards of reliability and validity in the sense that psychologists understand it. Since no attempt had been made to investigate these aspects of Touwen's Examination, we included an investigation of the reliability (Kakebeeke et al., 1993) and validity (Schoemaker et al., submitted) of the Examination in the present study. Both aspects of the Examination proved reasonably satisfactory adding further support for the significance of the findings reported here.

General motor competence

As shown in Table 6.3, prematurely born children showed less proficiency in the tasks included in the Movement ABC Test than their peers. This finding too is consistent with studies that have used previous versions of the same assessment (e.g. Marlow et al., 1989) or other scales (e.g. Abel Smith & Knight-Jones, 1990; Neligan et al., 1976; Nickel et al., 1982; Siegel, 1982).

In the present study, 6 items of the Movement ABC Test clearly discriminated between the premature children and their peers and 1 other item approached significance. The item that did not reach statistical significance was bicycle trail ($p<.05$). In addition, performance of the non-preferred hand on the posting coins did not differ between the groups ($p>.05$). These observations are in agreement with those of Marlow et al. (1989) who reported a significant difference in performance at 6 years of age between low birthweight children (<1251 grams) and classroom controls on the posting coins (preferred hand), threading beads, bean bag catching, ball rolling, balancing on either leg, and

walking on tip-toes items (all p<.01). Similarly, the difference between the groups on the bicycle trail and the non-dominant hand on the posting coins task did not exceed a probability level of .05. Furthermore, Nickel et al. (1982) noted impaired fine and gross motor skills, especially in the area of static balance.

Table 6.3: Performance of the premature and reference groups on the items of the Movement ABC Test (median, range).

Item	Premature	Reference	p^
Posting coins (sec)			
Pref. hand	17 (13-72)	16.5 (13-22)	**
Non-pref. hand	19 (15-84)	19 (15-28)	ns
Threading beads (sec)	47 (18-191)	43 (28-74)	****
Bicycle trail (errors)	1 (0-16)	0 (0-6)	*
Catching beanbag (catches out of 10)	9 (0-10)	9 (1-10)	****
Rolling ball (goals out of 10)	6 (0-10)	8 (3-10)	***
One-leg balance (sec)			
Right leg	20 (0-20)	20 (4-20)	***
Left leg	20 (0-20)	20 (9-20)	***
Jumping over cord			
pass knee height	146	86	**
pass lower height	3	1	
fail	23	1	
Walking on tip-toe (steps out of 15)	15 (0-15)	15 (9-15)	****

^ Mann-Whitney U test except for jumping cord=chi-square
* p<.05; ** p<.01; *** p<.001; **** p<.0001

Constructional skills

Developmental Test of Visual-Motor Integration

Some of the studies that either used the Bender-Gestalt or, like the present study, the Developmental Test of Visual-Motor Integration, found premature children to be less able to copy line drawings than fullterm children (e.g. Blackman et al., 1987; Klein et al., 1985, 1989; Taub et al., 1977) while others did not (Lowe & Papile, 1990; McDonald et al., 1989). The present study also found a significant difference between a reference group of 6-year-olds and premature children on this aspect of visuo-motor performance (Table 6.1). There was, however, considerable variability in scores among the premature children and some performed as well as the reference children.

Performance on the Griffiths form board

Although there was a difference between premature and reference children on the time taken to complete the Griffiths form board (Table 6.1), the large majority of children from both groups commented that it was an easy task to do. Griffiths reported that 57% of all 6-year-olds tested in the 1960s for the standardization of the Scales were able to complete the form board within 40 seconds. This compared to 84% of the reference children tested for the present study and 64% of the premature children. This suggests an upward drift in competence on constructional tasks since the 1960s which parallels that reported in cognitive ability generally (Fuggle et al., 1992). One possible explanation of this finding may be the increasing number of children in recent years who attend playgroups at an early age and are, therefore, more often exposed to this type of activity than children 30 years ago.

As far as we are aware only one study exists which investigated performance of 9 'at risk' and 20 normal fullterm children on the Goddard form board task (Jensen et al., 1988). This study did not report a difference in the time taken to complete the Goddard form board between the two groups at the age of 6 years. Our findings on the Griffiths form board which contains similar shapes to that of Goddard are, therefore, not in agreement with those of Jensen and colleagues. However, the 2 studies differed in the number of children assessed and the type of population studied (i.e. only 4 out of the 9 'at risk' children in Jensen et al.'s study had birthweights <2500 grams).

Apart from time taken to complete the form board, the number of errors made while inserting the eleven shapes of the Griffiths form board were also recorded (not shown in Table 6.1). There was a difference in the range of errors among the premature (0–6) and reference children (0–2), but the median number of errors was equal for both groups (median=0) (Mann–Whitney U; $p>.05$).

In Chapter 9 of this thesis we will consider performance of the premature children and the reference children on this and another form board task in more detail.

Teachers' perception of perceptuo–motor competence

Of the 172 Movement ABC Checklists sent to teachers, 74% were returned. To investigate whether or not there was a bias towards a lower response rate for children found to have difficulties on individual examination, the two groups of children whose teacher did (n=128) or did not (n=44) return the Checklist were compared on the main assessments. No differences emerged between the groups on total neurological optimality score or time to complete the Griffiths form board. The children whose teacher did not return the Checklist, however, were somewhat poorer on the Movement ABC Test ($p<.05$) and Visual–Motor Integration task ($p<.05$).

The median total item score for the premature children on section 1 to 4 of the Checklist was 0.72 (range=0–2.41). This did not differ significantly from the ratings (median=0.74; range=0–2.30) given by teachers of the reference group ($p>.05$). Neither did the two groups differ in the separate scores for each of the four sections of the Checklist (all $p>.05$).

Relationships among the neurological and perceptuo–motor assessments

The Spearman rank–order correlation coefficients (r_s) of the main assessments for the complete cohort (n=172) are shown in Table 6.4. For ease of reading negative coefficients have been changed to positive ones so that directions between the various measures are consistent.

Table 6.4: Spearman correlation coefficients (r_s) on the neurological and perceptuo-motor assessments for all premature children (n=172).

	Movement ABC Test	Visual-Motor Integration	Griffiths Form board	Movement ABC Checklist
Touwen's Examination	.50 ***	.32 ***	.31 ***	.53 ***
Movement ABC Test	-	.31 ***	.35 ***	.44 ***
Visual-Motor Integration	-	-	.43 ***	.39 ***
Griffiths form board	-	-	-	.30 ***

*** p<.001

The data for the whole group of premature children showed statistically significant but fairly low correlations between the measures. This pattern of correlations was what we would have predicted. Scores on the three general assessments (Touwen's neurological Examination and the Movement ABC Test and Checklist) correlated more highly with each other, than they did with the two more specific assessments (Developmental Test of Visual-Motor Integration and the Griffiths form board). Similarly, scores on the latter 2 assessments correlated higher with each other than with the global assessments. Although statistically significant, the percentage of variance accounted for ranged from approximately 10% to 25%, confirming our view that a range of assessments is needed to obtain an overview of children's perceptuo-motor performance.

Associated problems [2]

Cognitive ability

The results of the comparison between the premature and the reference groups on the British Ability Scales are shown in Table 6.5.

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[2] *As previously described in this thesis, the use of the term 'associated problems' to describe cognitive ability, behaviour and self-concept of children is entirely arbitrarily. It was simply done to emphasize the fact that the primary focus of this thesis is on neurological status and perceptuo-motor competence.*

Table 6.5: Performance of the premature and reference groups on selected components of the British Ability Scales (mean, SD).

	Premature (N=172)	Reference (N=215)	F	p ^
Short-form IQ	104.68 12.97	115.17 13.31	60.70	****
Matrices	55.48 8.41	56.67 10.62	1.42	ns
Similarities	54.14 7.21	61.44 9.21	72.57	****
Naming Vocabulary	47.97 9.88	58.02 9.96	97.96	****
Digit Span	51.25 8.02	53.04 8.69	4.35	*
Word Reading	45.71 9.58	50.02 14.34	11.45	***

^ one-way ANOVA; * p<.05; *** p<.001; **** p<.0001

At first sight, the short-form IQ scores of the premature children seemed reassuring compared with a notional mean of 100. However, in fact their scores were significantly lower than that of the reference children whose mean score was 115. On the five individual Scales, the direction of the differences between the two groups was consistently in favour of the reference children. Comparisons on two Scales (both measuring separate aspects of verbal ability: Similarities and Naming Vocabulary) reached statistical significance. Two recent studies involving low birthweight cohorts have found a similar upward drift in IQ scores among both index and control groups (Marlow et al., 1989; Astbury et al., 1987). Moreover, when Fuggle et al. (1992) examined a large group of 5-year-olds in Britain on the WPPSI between 1987-1990 and compared their performance to that of children tested in 1967 on the same version of the WPPSI they found that the mean full scale IQ score had increased 8 points in favour of the most recently tested children. Although explanations for this (continuing) rise in IQ scores have not been found the findings of the present study are not exceptional.

Behaviour

Premature children were not perceived by their parents or teachers as having more behavioural problems than reference children (Table 6.6). Actually, the opposite seemed true. Parents of children participating in the TCRU Day-Care project (see Chapter 5) reported a higher prevalence of behaviour problems.

Table 6.6: Scores on the Rutter Scale by parents and teachers of premature and reference children (median, range, N).

	Parents	Teachers
Premature	9 2–30 167	4 0–30 125
Reference	12 1–45 204	4 0–35 192
p ^	***	ns

^ Mann-Whitney U test; *** p<.001

Self-concept

The responses of the premature and reference children on the Pictorial Scale of Perceived Competence and Social Acceptance did not differ on questions regarding their cognitive competence, peer acceptance and relations with their mother (Table 6.7). For the domain of cognitive competence this was a slightly surprising outcome given that our objective measure of cognitive ability did differentiate the groups. However, it may well be that children of this age are not yet able to perceive problems of this kind. Even more surprising, however, was the finding that prematurely born children tended to feel more competent in physical activities than their peers although the difference in scores was small. The possible reason for this is discussed later in this Chapter.

Table 6.7: Responses on the self-concept Scale by the premature and reference groups (median, range, N).

	Cognitive	Peer	Physical	Maternal
Premature	3.33 1.17-4.00 168	3.17 1.33-4.00 168	3.33 1.33-4.00 168	2.75 1.50-4.00 166
Reference	3.33 1.33-4.00 214	3.17 1.67-4.00 214	3.17 1.50-4.00 214	3.00 1.40-4.00 208
p ^	ns	ns	**	ns

^ Mann-Whitney U test; ** p<.01

Relationships between the neurological, perceptuo-motor and other assessments

Cognitive ability

Scores on each of the four main assessments were correlated with the short-form IQ score to investigate the association between cognitive ability on the one hand and neurological status and perceptuo-motor competence on the other hand. The correlation coefficients for the neurological optimality score, Movement ABC Test scores or teacher Checklist scores were all very low (maximum r_s=.25). The most consistent finding was a weak but positive relation between overall short-form IQ scores and the two constructional assessments. Coefficients for the Visual-Motor Integration Test and time to complete the Griffiths form board were r_s=.43 (p<.0001) and r_s=.34 (p<.0001), respectively [3] .

Behaviour

When the behaviour scores reported by *parents* were correlated with the four main assessment scores, only the coefficient for the Movement ABC Checklist reached statistical significance (r_s=.27, p<.01). In general, behaviour scores provided by *teachers* correlated more highly than those of the parents and the coefficient of the Movement ABC Checklist indicated the strongest relationship (r_s=.46, p<.0001).

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[3] *In addition, verbal ability scores (i.e. the average score on the Similarities and Naming Vocabulary Scales of the BAS) also correlated significantly with performance on the Developmental Test of Visual-Motor Integration and the Griffiths form board. The coefficients were r_s=.32 and r_s=.27, respectively (both p<.01).*

6.3 Neonatal and demographic variables: their relation to neurological status and perceptuo-motor performance

Although many researchers recognise that birthweight and gestational age are not the only *neonatal* variables which are related to global outcome (e.g. Kopp & Krakow, 1983), they have been investigated most in relation to later outcome. Similarly, the main *demographic* variables that are usually considered in relation to the development of premature children are gender, ethnic origin and some measure of a child's family milieu. However, with the exception of gender, these factors have not been examined in relation to perceptuo-motor performance. In what follows, the influence of these selected variables on the children's neurological status and perceptuo-motor performance at 6 years of age is examined.

Neonatal variables: birthweight and gestational age

Birthweight

In 1961, the World Health Organization (WHO) suggested that all babies with a birthweight below 2500 grams should be described as 'low birthweight' (LBW) (Aylward & Pfeiffer, 1989). This group was then further sub-divided into very low birthweight (VLBW) children weighing less than 1500 grams, and extremely low birthweight (ELBW) children weighing less than 1000 grams. Table 6.8 summarizes the performance of all premature children sub-divided according to this WHO classification.

Table 6.8: Neurological status and perceptuo-motor performance in relation to birthweight in grams (median, range).

	ELBW < 1000 (n=39)	VLBW 1000-1499 (n=83)	LBW 1500-2499 (n=50)	p^
Touwen's Examination *total optimality score*	35 12-45	37 0-46	39 3-45	ns
Movement ABC Test *total score*	9 0-40	5.5 0-40	4 0-39	ns
Visual-Motor Integration *standard score*	7 1-11	8 0-13	9 3-15	**
Griffiths form board *time to complete (sec)*	41 22-210	34 23-210	34 23-97	**

^ Kruskal-Wallis one-way ANOVA; ** p<.01

Overall, it was the ELBW group who stood out as being less proficient on each assessment than their VLBW and LBW peers. However, group differences only reached statistical significance on the Visual-Motor Integration Test and the Griffiths form board. Post-hoc analyses showed that the ELBW children differed significantly only from the LBW children on both these measures ($p<.05$). In addition, ELBW children were significantly slower than the VLBW children on the Griffiths form board ($p<.05$). These findings are in agreement with others who used the same birthweight categories (e.g. Crowe et al., 1988; Saigal et al., 1990; The Scottish Low Birthweight Study Group, 1992).

Gestational age

In the present study, children born at 34 weeks of gestation or less were included. These were further sub-divided into those born between 25 and 27 weeks, 28 and 29 weeks, 30 and 32 weeks, and 33 to 34 weeks (De Vries, 1987). Table 6.9 summarizes the outcome of these four groups. From this Table it can be seen that children born between 25 and 27 weeks of gestation tended to obtain the poorest scores on all assessments, while children born between 33 and 34 weeks of gestation generally obtained the best scores. Post-hoc analyses showed that these two groups differed significantly in the number of minor neurological signs, Movement ABC Test and Visual-Motor Integration scores, as well as the time taken to complete the Griffiths form board.

Table 6.9: Neurological status and perceptuo-motor performance in relation to gestational age in weeks (median, range).

	25-27 (n=31)	28-29 (n=38)	30-32 (n=79)	33-34 (n=24)	p^
Touwen's Examination *total optimality score*	43 2-43	37 12-46	38 0-46	40 33-45	**
Movement ABC Test *total score*	11 0-40	7.3 0-39	4.5 0-40	2.3 0-14	***
Visual-Motor Integration *standard score*	8 0-13	7 0-11	8 0-14	9 5-15	*
Griffiths form board *time to complete (sec)*	42 23-176	36 26-210	34 23-210	32 22-97	**

^ Kruskal-Wallis one-way ANOVA; * $p<.05$; ** $p<.01$; *** $p<.001$

In addition, children born between 28 and 29 weeks of gestation were also poorer on the Movement ABC Test and Visual-Motor Integration Test than the 'oldest' premature children. Finally, children born between and 30 and 32 weeks of gestation were significantly faster than the 'youngest' premature on the Griffiths form board. Our findings are in agreement with those of, for example, Largo et al. (1989) who also reported a significant relationship between gestational age and outcome at school age [4].

The relationship between neonatal variables and teachers' judgements

Gestational age, rather than birthweight, was associated with teacher Checklist scores. Children born between 25 and 27 weeks of gestation were rated as significantly less competent in perceptuo-motor activities (median=1.17, range=0.04-2.41) than children born between 33 and 34 weeks of gestation (median=0.42, range=0-1.24) ($p<.01$).

Demographic variables: gender, ethnic origin, mother's educational level

Gender

Gender differences in perceptuo-motor performance in this sample of children were apparent for only two out of the four assessments. As can be seen from Table 6.10, boys obtained lower neurological optimality and Visual-Motor Integration scores. This same disadvantage for boys has been observed in several other studies (Drillien et al., 1980; Dunn, 1986; Neligan et al., 1976). For example, Largo et al. (1990a) found a small but consistent gender difference in neurological outcome in favour of both preterm and fullterm girls at 5-6 years of age.

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[4] *In addition to examining birthweight (BW) and gestational age (GA) independently from each other, a series of analyses was run to examine the combined effect of these on neurological status and perceptuo-motor performance. The 119 children who had a BW appropriate for their GA (AGA), the 26 children with a BW between the 10th and 3rd centile for their GA (SGA), and the 27 children with a BW below the 3rd centile for their GA (extremely SGA), did not differ significantly from each other on any of these measures.*

Table 6.10: Gender differences in relation to neurological status and perceptuo-motor performance (median, range).

	Boys (n=83)	Girls (n=89)	p^
Touwen's Examination *total optimality score*	36 2-45	39 0-46	**
Movement ABC Test *total score*	6 0-39.5	5 0-40	ns
Visual-Motor Integration *standard score*	8 0-15	9 0-14	**
Griffiths form board *time to complete (sec)*	36 23-145	35 22-210	ns

^ Mann-Whitney U test; ** p<.01

Ethnic origin

Table 6.11 summarises the findings on the assessments in relation to the ethnic origin of the children.

Table 6.11: Ethnic origin in relation to neurological status and perceptuo-motor performance (median, range).

	Caucasian (n=129)	Afro-Car. (n=29)	Asian (n=14)	p^
Touwen's Examination *total optimality score*	38 0-46	40 0-46	38.5 12-45	ns
Movement ABC Test *total score*	5 0-40	7.5 0-40	4.8 0-27.5	ns
Visual-Motor Integration *standard score*	8 0-15	8 0-13	8 6-13	ns
Griffiths form board *time to complete (sec)*	35 22-210	36 23-210	36 27-97	ns

^ Kruskal-Wallis one-way ANOVA

The heterogeneity of the population in London and surrounding areas in terms of ethnic origin was reflected in our sample. The majority of children were of caucasian origin (75%), followed by those of Afro-Caribbean (16%) and Asian (9%) descent. No

differences attributable to ethnic origin groups emerged on any of the assessments.

Mother's educational level

As a measure of family milieu the present study took mother's level of education as an index. Although this is one of the most widely used marker variable (Aylward & Pfeiffer, 1989) it is recognized that this may not be an adequate measure given the importance of other factors such as social support, parental attitudes etc.. However, maternal educational level was the best measure available to us. Following the interview with the paediatrician, mothers' level of education was classified into four categories: primary school only, secondary school, college or further education (e.g. secretary course), and a university degree. When the perceptuo-motor performances of the children in these four groups was examined no statistical differences were found (Table 6.12).

Table 6.12: Mother's educational level in relation to neurological status and perceptuo-motor performance (median, range) ^.

	0 ~ (n=7)	1 (n=85)	2 (n=57)	3 (n=16)
Touwen's Examination *total optimality score*	38 34-42	38 12-45	38 12-46	38 28-46
Movement ABC Test *total score*	7 1-20.5	6 0-38	4.5 0-30	3 0-22.5
Visual-Motor Integration *standard score*	6 5-11	8 0-14	8 4-13	8 6-13
Griffiths form board *time to complete (sec)*	37 30-97	36 22-176	33 23-145	34 28-62

^ Kruskal-Wallis one-way ANOVA; none of the comparisons significant.
~ 0 = primary school; 1 = secondary school; 2 = college or additional training; 3 = university.

The findings for neurological optimality are in agreement with some studies which report that the relationship between social class and neurological development is either absent or obscure (Taylor, 1987). However, other studies have found a relation between social class and minor neurological dysfunction. For example, Hadders-Algra (1987) found children from lower social class backgrounds to exhibit more minor neurological signs at

follow up. This corresponds to the low, but significant, correlations found between maternal educational level and perceptuo-motor functioning in a study by Blackman et al. (1987) among high-risk children at 5 years of age.

The relationship between demographic variables and teachers' judgements

Of the three demographic variables, only gender slightly influenced a child's perceptuo-motor competence in school activities (Mann-Whitney U; $p<.05$). Boys were rated less competent.

6.4 Prevalence of children with perceptuo-motor problems

So far, we have shown that the group differences between premature and reference children all reached statistical significance on the neurological and perceptuo-motor measures. We now turn to a more detailed analysis of perceptuo-motor problems *within* the premature group. Following the discussion in Chapter 3 on the definition and inclusion criteria of children with perceptuo-motor problems a distinction is drawn between children who were clearly classified as having a central motor deficit and those who did not meet these criteria.

Children with a central motor deficit

Twenty-six out of the 183 children in the full cohort had developed a central motor deficit. Of these, we tested 15 children at 6 years of age. As can be seen from the individual data presented in Table 6.13, variability of perceptuo-motor performance among these children was great. Due to the nature of their physical impairment some children were only able to attempt a few of our tasks whereas others were able to try nearly all. Similarly, their short-form IQ scores showed a wide range, with the poorest child obtaining a score of 68 and the brightest child 116 (mean=92.33; SD=14). In addition, the parents of 8 children reported a variety of behaviour problems. Our own clinical observations while assessing these children was that they sometimes displayed signs of frustration when attempting to complete the tasks. As their concentration drifted it was difficult to keep them motivated to carry on. However, the relationship between behaviour and performance is probably much more complex and may involve, among other factors such as the way the children perceive themselves as being physically

competent or not (see later). In Chapter 7 we will discuss the performance of these children in relation to the brain lesion observed in the neonatal period.

Table 6.13: Individual data of children with a central motor deficit who were assessed at 6 years of age.

Ss	Classification	Touwen	ABCT	VMI	Grif	ABCC	SIQ	Rutp
1	diplegia	29	7.5	10	67	1.39	100	8
2	hemi/triplegia	21	17.5	10	145	1.64	116	3
3	hemiplegia	16	26.0	8	31	0.51	108	7
4	diplegia	23	19.5	6	53	-	106	8
5	hemiplegia	12	29.0	0	101	2.04	90	3
6	hemiplegia	12	30.0	4	75	0.72	86	15
7	hemiplegia	18	22.5	6	44	2.14	105	5
8	di/quadriplegia	2	39.5	0	95	2.41	68	30
9	di/quadriplegia	3	39.0	4	74	1.57	86	22
10	diplegia	17	39.0	1	210	2.13	73	16
11	diplegia	12	27.5	7	36	1.49	97	23
12	di/quadriplegia	0	39.5	0	180	2.20	91	18
13	hemiplegia	20	25.0	4	37	-	103	10
14	hemiplegia #	13	-	-	-	-	83	21
15	quadriplegia	0	-	-	210	-	73	22

Legend: Touwen=total neurological optimality score; ABCT=total normative score Movement ABC Test (maximum score if item could not be performed); VMI=standard score Developmental Test of Visual-Motor Integration; Grif=time to complete the Griffiths form board (sec); ABCC=total score Movement ABC Checklist for teachers; SIQ=short-form IQ score; Rutp=total score Rutter scale for parents; #=blind child; -=not assessed.

Children with or without perceptuo-motor difficulties ('clumsiness')

As discussed in Chapter 3, a limitation in comparing the prevalence of perceptuo-motor problems (excluding a central motor deficit) across various cohorts is the limited number of standardised assessments on which such estimates are based and the arbitrary cut-off

points below which a child is identified as having a problem. In the present study we evaluated a child's performance on four standardised assessments and set the cut-off point for identifying premature children who performed inferiorly on one of these four assessments below the 15th centile of scores obtained by the reference children. In this way it was possible to indicate the proportion of premature children below average on each assessment and to compare this across assessments. In addition, the proportion of children whose performance fell below the 5th centile was calculated to explore how many children of below average ability experienced severe problems. These same cut-off points have been used in other studies involving 'at risk' children (e.g. Michelsson & Lindahl, 1993). Table 6.14 summarizes these percentages across the main assessments. In addition, in later Chapters we have applied the same principle to the examination of the children's performance on individual items *within* assessments.

Table 6.14: Cut-off point, N and percentage of premature children not classified as having a central motor deficit (n=156) whose performance fell below the 15th or 5th centile of scores of reference children.

	< 15th centile	< 5th centile
Touwen's Examination *total optimality score*	< 36 n=48 31%	< 33 n=26 17%
Movement ABC Test *total score*	> 5.5 n=69 44%	> 10.5 n=30 19%
Visual-Motor Integration *standard score*	< 7 n=27 17%	< 6 n=15 10%
Griffiths form board *time to complete (sec)*	> 42 n=37 24%	> 61 n=12 8%

As can be seen from this Table, the proportion of prematurely born children exceeded the population estimates on all four assessments. In the case of the two broad based assessments, Touwen's neurological Examination and the Movement ABC Test, this proportion was more than double when either the 15th or 5th percentile value was used.

In contrast, on the other two assessments which were narrower in focus, these proportions were smaller.

As a crude measure of the extent of the perceptuo-motor problems in the cohort, a simple count was made of children whose performance fell below the 15th centile across all four assessments or who were below average on three, two, or one assessment as compared to the number of children who failed none (Table 6.15).

Table 6.15: Distribution of children failing none, one or more assessments (<15th centile).

fail	4	3	2	1	0	total
N	8	15	27	50	56	156
%	5.1	9.6	17.3	32.1	35.9	100

Fifty-six (35.9%) children passed all four standardised perceptuo-motor assessments when total scores were considered. The remaining 100 children failed one or more assessments. This last group will be referred to throughout the remainder of this thesis as those having a perceptuo-motor problem.

Prevalence of perceptuo-motor problems according to teachers

Perhaps surprisingly, only 9 out of the 117 teachers who returned the checklist (8% of all children without a central motor deficit) judged the perceptuo-motor competence of the premature child in their classroom to be below average (< 15th centile) as compared to teachers of reference children [5] . In 7 children there was a high agreement between the teacher's judgement and scores on the perceptuo-motor assessment which resembles most closely the questions in the Checklist, namely the Movement ABC Test. Five children had obtained total Movement ABC Test scores which fell below the 5th centile (> 10.5) and two children's score fell below the 15th centile (> 5.5). The remaining two children, however, had a total normative score of 1 and 2, respectively.

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[5] *When the Checklist scores given by the teachers of children with a central motor deficit were included, the total percentage of children judged by their teacher as having perceptuo-motor problems rose to 13 %.*

Clearly, these results are somewhat puzzling and require further investigation. However, one aspect of our results which was reassuring was that there was a relation between the teachers' perception of perceptuo-motor competence and the number of individually administered standardised assessments failed. Children who failed one or more of the four main assessments obtained a significantly higher Checklist score (median=0.73; range=0.10–1.95) than those who passed all four assessments (median=0.50, range=0–1.70) ($p<.05$), and the other 3 groups obtained intermediate scores. This relation is graphically depicted in Figure 6.1.

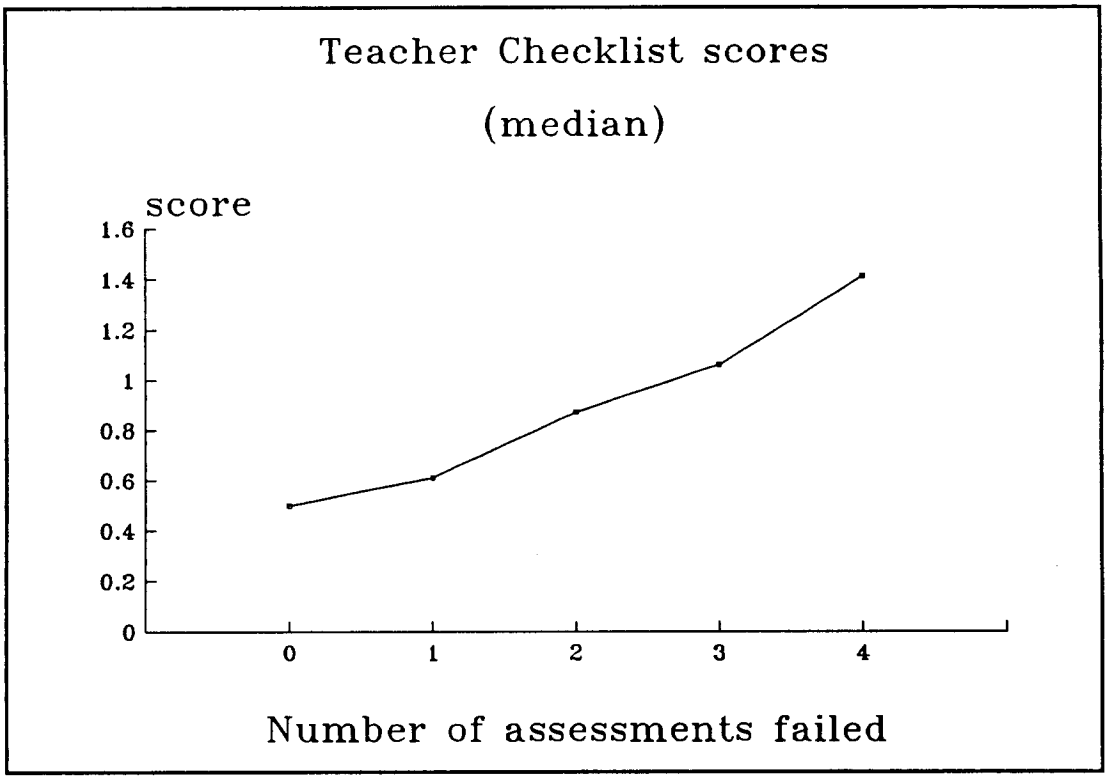

Figure 6.1: Median Checklist scores according to number of assessments failed.

A Kruskal–Wallis oneway ANOVA showed a main effect of group ($p<.01$). Post-hoc analysis further revealed that the scores obtained by children who failed 3 or 4 assessments differed significantly from those of children who failed none or one assessment.

Associated problems

Just as there is variability among the premature children in the absence, presence and extent of perceptuo-motor problems, it has been shown that they vary in whether they have associated problems or not. A brief sketch of the cognitive ability, behaviour and self-concept characteristics of the children is provided below.

Cognitive ability and behaviour

As a group, the 100 premature children with perceptuo-motor problems tended to be of lower cognitive ability than the 56 premature children without perceptuo-motor problems ($F=4.09$, $df=1,155$; $p<.05$). Mean short-form IQ scores were 104 (SD=12) and 109 (SD=11), respectively. However, it was of interest to note that when the Word Reading scores, which can be regarded as a more direct measure of academic attainment, were considered the two groups did not differ significantly from each other ($F=1.75$, $df=1,155$; $p>.05$). The results on the behaviour scores were equivocal. Whereas parents perceived no difference in behaviour between the children with or without perceptuo-motor problems, teachers did ($p<.05$).

To gain a more specific overview of the prevalence of associated problems we identified those children whose short-form IQ and Word Reading scores fell below the 15th centile. In addition, behaviour scores given by both parents and teachers were examined. Instead of using the 15th centile for these scores, however, we used Rutter's (1965; 1967) recommended cut-off points: a score of 13 or more on the parent Scale and a score of 9 or more on the teacher Scale. This latter decision was made since we were concerned about the reference sample's scores as will be explained later in the discussion of this Chapter. The results of this descriptive analysis are summarised in Tables 6.16a and are presented in detail in Table 6.16b.

Table 6.16a: Prevalence of associated problems among children without or with perceptuo-motor problems (summary).

	Associated problems			
	None	Cognitive only	Behaviour only	Cognitive and behaviour
children **without** perceptuo-motor problems (n=56)	43%	16 %	30 %	11 %
children **with** perceptuo-motor problems (n=100)	33%	29 %	17 %	21 %

As can be seen from Table 6.16a, 57% of premature children without perceptuo-motor problems presented with additional problems as opposed to 67% of children with perceptuo-motor problems. This difference did not reach statistical significance (X^2=1.50, df=1; p>.05). The majority of children showed either cognitive or behaviour problems in isolation but it was interesting to note that isolated behaviour problems occurred nearly twice as frequently as isolated cognitive deficits among children without perceptuo-motor problems and the opposite was true for children with perceptuo-motor problems.

Cognitive and behaviour problems co-occurred in 11% of children without perceptuo-motor problems. This percentage was slightly higher among children with perceptuo-motor problems (21%). However, it is noteworthy that 33% of children with perceptuo-motor problems did not show any associated problems. This means that for 1 in 3 children the perceptuo-motor problems were truly specific.

Table 6.16b: Prevalence of associated problems among children without or with perceptuo-motor problems (detail).

	Children without perceptuo-motor problems (n=56)	Children with perceptuo-motor problems (n=100)			
		Number of assessments failed			
		1 (n=50)	2 (n=27)	3 (n=15)	4 (n=8)
Single associated problem					
<15th SIQ	6	5	5	3	1
<15th Word Reading	1	3	1	1	1
Rutter parent *	14	6	4	1	1
Rutter teacher *	3	2	1	1	–
Two associated problems					
<15th SIQ and <15th Word Reading	2	3	3	2	1
Rutter parent and Rutter teacher	–	–	–	1	–
<15th SIQ and Rutter parent	–	2	4	1	–
<15th SIQ and Rutter teacher	–	1	–	–	–
<15th Word Reading and Rutter Parents	1	2	–	–	–
Three associated problems					
<15th SIQ and <15th Word Reading and Rutter parents	2	2	2	1	2
<15th SIQ and <15th Word Reading and Rutter teacher	1	–	1	–	–
<15th Word Reading and Rutter parents and Rutter teacher	1	1	–	–	–

continued.....

Table 6.16b: ..continued.

Four associated problems					
<15th SIQ and <15th Word Reading and Rutter parent and Rutter teacher	1	1	-	1	-
Total	32 (57%)	28 (56%)	21 (78%)	12 (80%)	6 (75%)

* scoring according to Rutter (1965; 1967)

Self-concept

In this study we were interested in the association between perceptuo-motor competence as measured in a standardised testing situation and the child's own view of his/her physical competence. When the children were sub-divided according to the presence or absence of perceptuo-motor problems, a Kruskal-Wallis oneway ANOVA on group by physical competence scores revealed a main effect of group ($p<.01$). Post-hoc analysis showed that the median physical competence score of children with a central motor deficit (median=2.67; range=1.33-4.00) was significantly lower than that of children with (median=3.50; range=1.67-4.00) and without (median=3.42; range=2.17-4.00) perceptuo-motor problems ($p<.05$).

6.5 Discussion

Neurological status and perceptuo-motor performance

In this Chapter the performance of 172 highly selected preterm children on a neurological Examination and various perceptuo-motor measures was compared to that of randomly selected samples of children at 6 years of age. Fifteen children were classified as having a central motor deficit ranging from hemiplegia to quadriplegia. When the 11 untestable children were added this makes a total prevalence of 14%. However, in addition many more children showed minor neurological signs or were experiencing mild to moderate perceptuo-motor problems at 6 years of age. A closer look at the individual items of the neurological Examination and Movement ABC Test showed that some items were more sensitive than others in detecting differences between the groups.

In general, correlations between the various measures were in the region of .40, suggesting that they were measuring related, but not completely overlapping, aspects of ability. From our point of view this outcome was especially interesting as it confirmed our belief that a very wide range of assessments is needed to provide a comprehensive picture of perceptuo-motor problems among prematurely born children. Of the four main assessments, performance on the Visual-Motor Integration Test and Griffiths form board related most strongly to short-form IQ scores.

Compared to the discriminative power of the individually administered standardised assessments, the teachers' responses at first sight seemed somewhat surprising as they did not discriminate between premature and reference children. However, the fact that the children whose teacher did not return the Checklist were less well coordinated on two of the four assessments might have partly biased the results on the Checklist toward children with 'relative' good perceptuo-motor competence. Also, whereas the teachers who participated in the standardisation of the Movement ABC Checklist were fully informed beforehand on the aims of this assessment and discussed aspects of perceptuo-motor development personally with the authors, teachers participating in the present study were presented with the Checklist without any such prior knowledge. In spite of these problems, there was a relationship between the degree of perceptuo-motor problems as measured on standardised assessments and teacher judgements within the premature group. Also, the correlation coefficients showed that our own observations related well to that of teachers. The least strong relationship was found for performance on the Griffiths form board. One possible explanation for this may be that problems with constructional skills are not sufficient to label a child as lacking perceptuo-motor competence across the whole spectrum of activities within the classroom.

Associated problems

The present study showed that, as a group, the premature children were of lower cognitive ability than the reference children when overall short-form IQ scores were examined. The only Scale included in the short-form procedure of the BAS which did not statistically differentiate between the groups was the Matrices. This was somewhat surprising as it was considered to be the most 'perceptually' loaded Scale. However, it should be noted that

the quality of the 'missing' shape (i.e. degree of resemblance with the target shape) which the child has to draw in the Matrices Scale is not a criterion on which his/her performance is evaluated. If this had been the case then we believe that the premature children would have scored less well than reference children.

Interestingly, preterm children were not perceived as exhibiting more behaviour problems either at home or in school. In fact, parents of the reference group reported a higher prevalence of behaviour problems. One possible explanation for this finding may be that the TCRU sample was (as explained in Chapter 5) not randomly selected but chosen for the background of the mother, i.e. in full-time employment before pregnancy and with the intention to return to work within 9 months after giving birth, resulting in the child being looked after during the day by someone other than the mother. Although we do not know the employment status of the mothers in our study around the time of birth of the child, approximately 20% of the children were reported by their parents as having been looked after by a different person than the mother or father between 0 and 2 years of age. As such, there is some overlap between the two samples. It is beyond the scope of this thesis to discuss the differences in environment in the early years of life and their impact on behavioural development of the child as well as on mother-child interaction, but it is conceivable that it plays a role in the reported differences in behaviour as perceived by parents. With hindsight, therefore, the reference group may not have been ideal but we had no better alternative. Nevertheless, the data yielded by both Rutter questionnaires provided valuable background information in this study.

Finally, we reported on the way premature children view themselves in four domains of every day life. As far as we are aware few other studies have included measures of this type. At the age of six, the premature children did not differ from age-matched peers with respect to judgements of cognitive competence or the way in which they felt accepted by their friends or mother. However, as a group, preterm children felt more superior in daily physical competence than reference children. Initially this came as a surprise as it was inconsistent with our own findings. However, when the scores of children with a central motor deficit were examined more closely it emerged that these children in fact were sensitive to their perceptuo-motor problems at 6 years of age.

The relationship between 'clumsiness' and self-esteem in older children has recently attracted considerable attention (Schoemaker, 1992). For example, Adler (1982) found that children with perceptuo-motor problems did not enjoy physical education or competition. Furthermore, Wall et al. (1985) have argued that a lack of confidence and negative affect toward physical activity are likely to result in less participation. This would prevent a child from increasing his/her skills thereby reinforcing the tendency to dislike situations which require perceptuo-motor competence. Wall et al. concluded that the relationship between perceptuo-motor problems and affect is likely to be more reciprocal than unidirectional. In the light of these findings it is therefore important that, like the present study, future studies should take notice of a child's attitude towards physical activity.

The influence of neonatal variables

Because both birthweight and gestational age have been shown to affect morbidity (Goldenberg et al., 1985) the influence of these variables was examined. In the present study, children with a birthweight below 1000 grams (ELBW) were found to be most affected in their neurological status and perceptuo-motor performance at 6 years of age. These findings are in agreement with other studies who also found that ELBW children performed less well at school age (e.g. Marlow et al., 1989; Portnoy et al., 1988). Similarly, when the premature children were sub-divided according to their gestational age those born earliest (i.e. between 25 and 27 weeks of gestation) showed the poorest performance despite the fact that many of the children born at a later gestational age had been the illest. Neither could our findings be explained by the fact that the children with a central motor deficit were over-represented in either the lowest birthweight or shortest gestational age category; 4 out of the 15 children we assessed were of ELBW, and 5 were born before 28 weeks of gestation.

We would like to draw attention to two methodological considerations with regard to follow up studies. First, despite the fact that the WHO classification system for low birthweight children is apparently internationally agreed, it is not universally applied and many studies use different cut-off points to create different categories (Touwen, 1986). For example, Stanley and English (1986) entered a child in their low birthweight study in Western Australia if its birthweight was below 2000 grams, as did Drillien et al.

(1980), Michelsson and Lindahl (1993), and Smith et al. (1982). Others investigated children weighing less than 1750 grams (e.g. Hertzig, 1981). It is obvious that if future follow up studies do not adhere to the WHO's classification of birthweight (or propose a well founded alternative classification system), differences in outcome between populations remain a source of debate because of different population characteristics.

Secondly, premature birth is defined as being born before term, i.e. before 37 weeks of gestation. However, as described in Chapter 1, the current technology available to Neonatal Intensive Care Units has meant that an increasing number of children born well before the 37th week may survive. Nowadays, infants of 23 weeks of gestation weighing between 500–750 grams are said to be viable and may survive (Yu et al., 1986; Wolke, 1991). This new generation of children has captured the attention of researchers to such an extent that there is even a trend to exclude the 'older' premature child from studies. Whereas earlier studies included all children born at 37 weeks or less, it is now common to include only all children born at 34 weeks or less. Nevertheless, Aylward and Pfeiffer (1989) found that out of the 81 studies on LBW children they reviewed, 30% did not report the gestational ages of the infants which clearly shows that there is still room for improvement in description of populations even today.

Influence of demographic variables

The relationships observed between the three demographic variables gender, ethnic origin and mother's educational level, and performance on the various measures in the present study were generally consistent with the current literature.

Although the differences were relatively minor, boys were poorer than girls on a number of assessments used in this study. These findings are in agreement with those of, for example, Aylward et al. (1987) who investigated the outcome of low birthweight children and found that the infant's gender did influence later motor function. These observations are in line with the specific vulnerability often found among males (Brothwood et al., 1986; Taylor, 1981). Although the precise mechanisms which underlie this vulnerability are not yet fully established, it is now known that each phase of brain development takes longer in males (Goodman, 1991) which in turn exposes them to a greater risk for factors

that disrupt a phase of development for a longer time. In addition, the influence of sex hormones (i.e. testosterone) is now thought to play a major role in male developmental disorders. For example, due to prenatal testosterone an abnormal reduction of neuronal and axonal death in the right hemisphere could be invoked, possibly resulting in developmental disorders affecting speech, language and reading (Galaburda et al., 1987 in Goodman, 1991). However, others have argued that the role of gender may be overruled by insults such as preterm birth, or brain injury sustained in the peri- or neonatal period (Hadders-Algra, 1987).

We could not detect any difference in perceptuo-motor ability at 6 years of age between prematurely born children of various ethnic origins. Because we are not aware of any follow up study which paid attention to this variable in relation to long term development it is difficult to interpret our findings. Anecdotal evidence suggests that particularly in the first years of life, children of Afro-Caribbean origin living in Great-Britain seem to be advanced in their gross motor behaviour compared to Caucasian children. However, it seems that once children of other ethnic origins have reached these motor milestones, the influence of cultural background on perceptuo-motor competence diminishes.

The 7 children whose mother did not have the opportunity to pursue any further education after leaving primary school obtained the poorest scores on the Movement ABC Test, the Developmental Test of Visual-Motor Integration and the Griffiths form board (see Table 6.14). However, no statistical differences in perceptuo-motor competence between children of mothers with various educational backgrounds emerged in the present study. While realising that our measure of socio-economic status was not the most ideal, these findings only partially support to the findings of several epidemiological studies which have suggested that a positive social environment can act as a compensating mechanism for the disadvantage of low birthweight. Perhaps the most influential work in this area has been that of Sameroff and Chandler (1975). They showed evidence in support of the view that a child's family milieu was more often implicated in poor developmental outcome than was any particular biological problem or medical complication. It was suggested, however, that there were exceptions, such as infants with severe neurological deficits or low birthweight children with concomitant cognitive or sensory impairment. Even in such

cases, however, development was a function of interactions between child and environment (Bradley and Casey, 1992). As a result, the focus of longitudinal studies shifted to the more complex relationships between biological and environmental factors. For example, Illsley & Mitchell (1984) conducted a 10-year cohort study of children with a birthweight below 2500 grams. They found that both a stimulating rearing environment and high academic attainment of parents were better predictors of 10-year IQ scores, perceptuo-motor skills, behavioural traits and academic attainment than birthweight. However, measuring the role of the environment in development remains one of the most problematic issues in follow up studies.

Children with perceptuo-motor problems

The present study has replicated and extended the findings of other studies that there is a higher prevalence of perceptuo-motor problems among prematurely born children. Most strikingly perhaps, was the high proportion of children who showed difficulty with the items included in the Movement ABC Test (< 15th centile; 44%). Even when the cut-off point was more strict (i.e. below the 5th centile), many more prematurely born children than expected were performing poorly. Similar findings have been reported by, for example, Michelsson and Lindahl (1993) who reported that 34% of low birthweight children assessed at 9 years of age obtained scores below 1 SD compared to controls and 16% obtained scores below 2 SDs on a previous version of the Movement ABC Test. Prevalence figures for below average performance on the Visual-Motor Integration Test and Griffiths form board task in the present study were generally lower which may be due to the specific nature of ability measured by these assessments. In summary, compared to estimates of 'clumsiness' in the general population which range from 5 to 10%, the present findings indicate that a considerable higher proportion of children born prematurely experience perceptuo-motor problems at 6 years of age than 'non-clinical' samples.

Based on the number of assessments failed, we decided to split the premature children into those without (pass all 4) or with (fail 1 or more) perceptuo-motor problems. The 56 children in the former, and 100 children in the latter group not only differed in their perceptuo-motor competence but also in their cognitive ability and behaviour as perceived

by teachers. Close inspection of the individual data showed that 11% of children without perceptuo-motor problems displayed a combination of cognitive and behaviour problems, whereas among children with perceptuo-motor problems this figure was 21%. On the other hand, approximately one third of children with perceptuo-motor problems did not show any associated problems. This outcome suggests that while most children with perceptuo-motor problems do have associated problems, there are some whose perceptuo-motor difficulties are truly specific.

It is interesting to note that among the premature children identified as having perceptuo-motor problems, a greater proportion had shown a brain lesion in the neonatal period. Whereas 24 out of the 56 children without perceptuo-motor problems had an abnormal ultrasound scan, this occurred in 68 out of the 100 children with perceptuo-motor problems (X^2=9.38, df=1, p<.01). However, this means that 32 children with perceptuo-motor problems had not been diagnosed as suffering from a brain lesion in the neonatal period and emphasises the multifactorial aetiology which is thought to underlie the problems these children develop (see Chapter 3). We will consider the association between the presence or absence of ultrasound abnormalities noted in the neonatal period and perceptuo-motor competence at 6 years of age in the next Chapter.

CHAPTER 7

Neonatal brain lesions and perceptuo-motor competence

7.1 Introduction

In the preceding Chapter we have shown that the undifferentiated cohort of premature children, as a group, were less proficient on all perceptuo–motor assessments and more likely to have associated problems than their age–matched peers. However, among this cohort were children who did or did not sustain a brain lesion early in life. Although it is recognised that the occurrence of an early lesion will not be the only risk factor which may affect the pathway of development it is nevertheless acknowledged to be an important factor which deserves separate attention [1] .

The aim of this Chapter is, therefore, to address a number of specific questions concerned with the observed state of the brain in prematurely born children at birth and later perceptuo–motor competence. Although the rationale for each of the questions addressed is presented in detail in Chapter 4, the first five of these form a coherent set dealing with the possible effects of lesions of different origins and extent. Among these, the entire spectrum of brain lesions is covered, ranging from a complete absence to the presence of 'major' lesions. In addition, the effects of isolated lesions are compared to the effects of lesions that occur in combination with each other.

A slightly different question is addressed at the end of this section namely, whether there is an association between the length of time isolated 'minor' ischaemic lesions were visible on ultrasound in the neonatal period (which may be an indication of varying pathology) and later outcome. In the present study we have this data available on a substantial number of children.

Finally, we consider the question of whether the different groups of children participating in the study exhibit different profiles of performance that relate in any way to the nature of their brain lesion. At this stage, the profiles examined are based on the norm–referenced neurological and perceptuo–motor assessments and cognitive ability and are

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[1] *The development of a lesion may well be a marker of an event (in most cases of unknown origin) which took place before, during or after birth and seems to be related to the gestational age of the infant. As such, a brain lesion is not an independent risk factor.*

purely descriptive, i.e. without recourse to the more sophisticated statistical procedures adopted in Chapter 8.

Methodological issues

Subject selection and grouping

In the introductory Chapters of this thesis two rather contradictory approaches to the study of neonatal lesions and their consequences were noted. In Chapter 1, the process of classifying lesions in the developing brain as an ongoing exercise with the tendency towards increased differentiation was clearly emphasised (e.g. Leviton & Paneth, 1990). In contrast, in Chapter 2 we noted that in some follow up studies children with different lesions were grouped together, often for reasons that were more to do with failure to achieve statistical significance than with logic. In the present study we have acknowledged the point made by Leviton and Paneth (1990) that the process of grouping children because their lesions 'look' similar is a dangerous exercise and have avoided such arbitrary decision making. This means that the 183 children reported in the study are divided into 21 groups that range in size from 1 to 64 children (see Table 5.4). However, none of the single case studies will be included in any group analyses reported in this Chapter.

Measures used

Although more precise, the questions set in this Chapter follow logically from those posed in the previous Chapter. Therefore, we continue to use the same measures of neurological, perceptuo-motor and 'associated problems'. Cognitive ability, behaviour and self-concept will, however, receive progressively less attention as the thesis proceeds in order to focus on perceptuo-motor competence.

Data analyses

To examine the differences and/or similarities between groups parametric (oneway ANOVA) and nonparametric (Kruskal-Wallis oneway ANOVA or Mann-Whitney U) statistical tests were applied as appropriate. As before, the alpha level was set at .01. Post-hoc analysis following the oneway ANOVA consisted of the Student Newman-Keuls test, while for the Kruskal-Wallis test the Multiple Comparisons Between Treatments procedure as described by Siegel and Castellan (1988) was calculated. In addition, the

Jonckheere test for ordered alternatives (Siegel & Castellan, 1988) was applied to data relating to the duration of flares. This nonparametrical analysis tests the hypothesis that the groups are ordered in a specific *a priori* sequence. The data are cast into a two-way table with each column representing each successive group in the arranged in the hypothesized order of medians. The Jonckheere test involves counting the number of times an observation in the *i*th group is preceded by an observation in the *j*th group. The Jonckheere test statistic J is then the total number of these counts. As the samples become large, the sampling distribution of J is approximately normal. Since the alternatives are ordered, the test is considered to be a one-tailed test.

7.2 Results

Where do children with normal ultrasound scans fall on the continuum of perceptuo-motor problems at 6 years of age?

To answer the above question, the performance of the 64 premature children with consistently normal ultrasound scans was contrasted to that of the reference groups and the 119 prematurely born children (including the 11 severely impaired) with a lesion.

Neurological status and perceptuo-motor competence

Table 7.1 summarizes the findings of the analyses. None of the 64 children developed a central motor deficit and their Visual-Motor Integration (VMI) scores or time to complete the Griffiths form board did not differ from that of reference children. However, this did not mean that premature children with a normal scan escaped completely unscathed. Their Movement ABC Test scores indicated that they were less well coordinated than the reference children (post-hoc $p<.05$), and as many as 22 children (34%) obtained total scores which put them in the bottom 15th centile. They were, however, definitely performing better at 6 years of age than those who suffered from a brain lesion in the neonatal period. On all five assessments comparisons reached statistical significance ($p<.01$).

Table 7.1: Neurological status and perceptuo-motor performance of reference children, premature children with a normal scan or abnormal scan (median; range).

	Reference	Premature normal scan	Premature abnormal scan	p ˜
Touwen's Examination *total optimality score*	41 (31-46)	40 (24-46)	35 (0-46)	****
Movement ABC Test *total score*	2 (0-26)	4 (0-23.5)	9 (0-40)	****
Visual-Motor Integration *standard score*	9 (4-15)	9 (6-14)	7 (0-15)	****
Griffiths form board *time to complete*	32 (20-94)	33 (22-101)	38 (23-210)	****
Movement ABC Checklist *total item score*	0.74 (0-2.30)	0.49 (0-1.62)	0.95 (.04-2.49)	****

˜ Kruskal-Wallis oneway ANOVA; **** p<.0001.

Teachers' perceptions of perceptuo-motor competence

Teacher's scores on the Movement ABC Checklist discriminated between the three groups (p<.0001). It was surprising, however, that the premature children without lesions were actually rated better in perceptuo-motor competence by their teachers than the reference group (post-hoc p<.05). A possible reason for this may be that the ratings given by teachers were influenced by their knowledge that the child was born prematurely. If so, the teacher may have rated the child as 'doing well' compared to the other children in the classroom.

Associated problems

Statistical analysis of the differences between the groups on the short-form IQ scores revealed a very similar pattern to that of the perceptuo-motor measures (F=44.66, df=2,397; p<.0001). Whereas the premature children with a consistently normal scan (mean=107; SD=11) were significantly less able than the reference children (mean=115; SD=13), their short-form IQ scores were significantly higher than that of premature children with lesions (mean=100; SD=17).

Similarly, a main effect of group was found for the total behaviour scores on the Rutter Scales for both parents ($p<.001$) and teachers ($p<.01$). Post-hoc analysis revealed that the parents of prematurely born children with normal scans perceived their off-spring as showing fewer behaviour problems than either the parents of reference children (post-hoc $p<.001$) or the premature children with lesions (post-hoc $p<.01$). The teachers only considered premature children with normal scans to show fewer behaviour problems than premature children with lesions (post-hoc $p<.01$).

Finally, self-concept did not seem to bear a strong relation to the neonatal status of the child. The group comparisons showed that neither prematurity without the concomitant problem of a brain lesion nor premature birth complicated by a brain lesion seem to affect the way children perceive themselves at 6 years of age compared to children with less turbulent medical histories [2] .

What is the range of perceptuo-motor impairment among children with 'major' haemorrhagic and/or ischaemic lesions?

The neonatologist (LDV) included the following children in the category of 'major' lesions: children with periventricular (PVL) or subcortical leukomalacia (SCL), a Grade III haemorrhage (involving the parenchyma), a definite infarct, or any combination of these (see Table 7.2). In addition, children with a Grade IIb (large intraventricular) haemorrhage with or without periventricular densities were included in this category since there are studies which suggests that these children generally have a poor outcome (e.g. Cioni et al., 1992; Van de Bor et al., 1993).

The full cohort included 29 children whose lesions were classified as 'major'. We assessed 18 of these at 6 years of age. The other 11 children (see Chapter 5 and Table 7.2) were not seen as it was known that the degree of their central motor deficit and/or mental impairment was such that they would not be able to complete our test battery.

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[2] *However, neonatal status may have an indirect effect on children's self-concept as it influences later perceptuo-motor competence which in turn is related to self-concept (see Chapter 6).*

Table 7.2: Distribution of 'major' haemorrhagic and/or ischaemic lesions.

Ultrasound findings	N	Assessed	central motor deficit
Grade IIb haemorrhage III haemorrhage	2 6	2 6	0 4
Grade IIb haemorrhage and flares	2	2	2
Infarct	2	2	1
Grade IIb haemorrhage and infarct	2	1	1
Grade IIb haemorrhage, flares, cyst and infarct	1	1	0
Cystic periventricular leukomalacia	7	3	7
Cystic periventricular leukomalacia and Grade IIa haemorrhage Grade IIb haemorrhage	 1 1	 1 0	 1 1
Cystic periventricular leukomalacia, infarct, Grade IIb haemorrhage and cyst	1	0	1
Cystic subcortical leukomalacia	3	0	3
Both cystic periventricular and subcortical leukomalacia	1	0	1
Total	29	18	22

Prevalence of central motor deficit among children with 'major' lesions

As can be seen from Table 7.2, the large majority of children with 'major' lesions were classified as suffering from a central motor deficit (n=22; 76%). However, the expression of these motor deficits were different. All 14 children with 'major' ischaemic lesions, i.e. extensive cystic PVL and/or SCL developed a severe central motor deficit. They were predominantly classified as di-/quadriplegic. In contrast, hemiplegia was the most common classification among the other 8 children with 'major' lesions.

In many ways, the more interesting aspect of our data was that 7 (24%) of the children with 'major' lesions had not developed a central motor deficit. This group comprised the 2 children with an isolated Grade IIb haemorrhage, 2 of the 6 children with a Grade III

haemorrhage, 1 of the 2 children with an infarct, 1 of the 2 children with a combination of a Grade IIb haemorrhage and infarct and a child with a combination of a Grade IIb haemorrhage, flares, cyst and infarct. It is still not known why these children did not develop any overt physically handicapping condition after they were diagnosed by means of brain imaging as suffering from these 'major' lesions the neonatal period.

Variability of outcome among the children with 'major' haemorrhages

Of the 6 children with a Grade III haemorrhage, 4 were found to have developed a hemiplegia (3 right-sided; 1 left-sided). One of these was blind due to retinopathy of prematurity and could, therefore, not be assessed on the perceptuo-motor measures (Table 7.3). The other 2 children did not show any 'hard' neurological signs (e.g. difference in muscle power, brisk reflexes or tone abnormalities) but did show considerable coordination difficulties especially on the manual dexterity items of the Movement ABC Test. Like their more severely affected peers, both children showed asymmetry in performance on the posting coins task (i.e. non-preferred hand considerably slower) and the one-leg balance task (i.e. difference in ability between the right and left leg).

Table 7.3: Outcome of children with a Grade III haemorrhage ˜.

	1	2	3	4	5	p ^
central motor deficit	Yes	Yes	Yes	No	No	
Touwen's Examination *total score*	12	12	18	35	35	**
Movement ABC Test *total score*	30	29	22.5	13	10.5	***
Visual Motor Integration *standard score*	4	0	6	9	5	**
Griffiths form board *time to complete*	31	33	101	75	44	ns
Movement ABC Checklist *total score*	0.72	2.04	2.14	0.57	1.70	*
British Ability Scales *short-form IQ*	86	90	105	110	88	*

˜ excluding one blind hemiplegic girl; ^ compared to children with a normal scan;
* p<.05; ** p<.01; *** p<.001

Their total scores on the Movement ABC Test put them in the bottom 5th centile as compared to age-matched reference children. The 2 children with an isolated Grade IIb haemorrhage showed surprisingly good levels of perceptuo-motor and cognitive competence. Their scores compared favourably with those of reference children. For example, their Movement ABC Test scores were 0 and 1, and short-form IQ were 103 and 111, respectively. In contrast, when a Grade IIb haemorrhage was accompanied by another lesion (4 children assessed), the picture changed considerably. Two out of these 4 children developed a central motor deficit. However, closer inspection of their individual scores across the perceptuo-motor and cognitive assessments showed that the girl's difficulties were global, while the boy had specific movement difficulties without accompanying cognitive deficits. The remaining 2 children with a combination of a Grade IIb haemorrhage and another lesion were also more poorly coordinated than their premature peers with an isolated Grade IIb haemorrhage (e.g. both obtained Movement ABC Test scores which fell below the 5th centile compared to reference children). However, neither of these 2 children were classified as having a central motor deficit.

Variability of outcome of children with extensive cystic PVL

Three children with cystic periventricular leukomalacia (PVL), and one child with a combination of cystic PVL and a Grade IIa haemorrhage were assessed at 6 years of age. All children attempted to complete the manual dexterity tasks included in the Movement ABC Test. The most rewarding and successful task was 'posting coins into a box'. All children completed this task in one way or the other but for one child it took a lot of effort to complete the task and she subsequently did not complete any of the other perceptuo-motor items. However, the other 3 children were able to insert the coins relatively fast with the preferred hand (29, 35 and 39 seconds; all within the bottom 5th centile). These same 3 children also attempted to complete the Visual-Motor Integration Test and the Griffiths form board. One boy produced reasonably good copies of the most simple shapes (standard score=4). He was also able to insert the shapes of the form board relatively quickly (74 seconds) without making any errors. It is interesting to note that this boy was the only one among children with extensive cystic PVL examined by us who had normal visual acuity and stereoscopic vision. The other 2 children were less successful on the copying and form board tasks (both Visual-Motor Integration scores=0; Griffiths form

board 95 and 240 seconds, 2 and 6 errors respectively). Short-form IQ estimates for these children were 86, 68, and 91, respectively.

Are isolated 'minor' haemorrhagic or ischaemic lesions associated with later perceptuo-motor problems?

'Minor' haemorrhagic or ischaemic lesions were classified as a Grade I or IIa haemorrhage either in isolation or in combination with periventricular densities (flares), or periventricular densities in isolation (see Table 7.4). In total, 81 children fell into this category. In addition, one girl with a small localized cyst was included because her lesion was too small to be described as a 'major' lesion and one boy was included because he showed a combination of a Grade IIa haemorrhage, flares and infarct. Since the haemorrhage did not involve the parenchyma and the echogenicities seen in the white matter did not break down to major cyst formation he was classified under the heading of 'minor' lesions.

Table 7.4: Distribution of 'minor' haemorrhagic and/or ischaemic lesions.

Ultrasound findings	N
Grade I haemorrhage IIa haemorrhage	10 8
flares	45
flares and Grade I haemorrhage Grade IIa haemorrhage	 10 8
Single small cyst	1
Grade IIa haemorrhage, flares and infarct	1
Total	83

Isolated 'minor' haemorrhagic lesions

The ultrasound scans of 10 children were classified as an isolated germinal matrix haemorrhage (Grade I) and 8 children were found to have sustained a larger haemorrhage extending downwards into the basal ganglia (Grade IIa). To investigate whether there was

a relationship between the occurrence of an isolated haemorrhage and later outcome, performance of these children was compared to that of the 64 children with consistently normal scans.

Neurological status and perceptuo-motor competence

None of the children with an isolated 'minor' haemorrhage were classified as having a central motor deficit at 6 years of age. Neither did their total neurological optimality scores or scores on any of the other perceptuo-motor assessments differ from that of children with normal scans (this included the individual items of the neurological Examination and the items of the Movement ABC Test). Nevertheless, as can be seen from the range of scores in Table 7.5, there were some children with 'minor' haemorrhagic lesions who were poorly coordinated for their age. In particular, 7 children (39%; 5 with a Grade I and 2 with a Grade IIa haemorrhage) obtained total scores on the Movement ABC Test which fell below the 15th centile. However, an equal proportion of premature children with normal scans were poorly coordinated for their age (22/64; X^2=0.13, df=1, p>.05) as well.

Table 7.5: Neurological status and perceptuo-motor competence of children with normal scans and isolated 'minor' haemorrhagic or ischaemic lesions (flares) (median; range).

	Normal (n=64)	Grade I (n=10)	Grade IIa (n=8)	flares (n=45)
Touwen's Exam. *total score*	40 (24-46)	38 (28-44)	41 (28-43)	36 (12-46)
ABC Test *total score*	4 (0-23.5)	5.3 (0-16.5)	1.3 (0-22)	7.5 (0-27.5)
VMI *standard score*	9 (6-14)	9 (5-11)	8 (6-11)	8 (3-13)
form board *time to complete*	33 (22-101)	36 (23-63)	38 (31-98)	36 (23-70)
ABC Checklist *total item score*	0.49 (0-1.62)	.69 (.14-1.30)	.64 (.48-.80)	.70 (.09-1.50)

Associated problems

The mean short-form IQ scores for children with normal scans (107; SD=11), an isolated Grade I haemorrhage (110; SD=12) or Grade IIa haemorrhage (101; SD=16) were not significantly different from each other. Neither were there any differences on the behaviour or self-concept measures between the groups.

Isolated 'minor' ischaemic lesions

Forty-five children were diagnosed as having periventricular densities (flares) in the neonatal period without any other ultrasound abnormality.

Neurological status and perceptuo-motor competence

In contrast to the children with 'minor' haemorrhagic lesions, 4 children with flares were diagnosed as showing definite signs of a central motor deficit. As can be see from Table 7.5, compared to children with consistently normal scans, children with flares also obtained significantly lower (i.e poorer) neurological optimality scores ($p<.01$) and higher (i.e. poorer) Movement ABC scores ($p<.01$) (the differences between the two groups approached significance for the Visual-Motor Integration Test ($p<.05$)). However, when the performance of children with various durations of flares were analyzed in more detail, a different picture emerged (see later in this Chapter for further discussion).

Associated problems

When the group of children with flares was considered as a whole, they did not differ significantly on any of the cognitive, behaviour or self-concept measures from children with consistently normal scans.

Does the co-occurrence of a 'minor' haemorrhagic and ischaemic lesion put a child at an increased risk for later perceptuo-motor problems?

Ten children showed a Grade I haemorrhage in combination with flares and a further 8 children were classified as having a combination of a Grade IIa haemorrhage with flares (Table 7.4). One of the children in the first group had a severe visual impairment which prevented her from completing a number of assessments. She has been excluded from the

analyses which are to follow.

Three analyses were performed. The first analysis focused on the comparison with children with normal scans. The second analysis compared performance of the children in the combined lesion groups to those who had shown similar haemorrhagic lesions but without further ultrasound abnormalities. For the third analysis, children with combined lesions were compared to all children with flares.

Comparison with children with normal scans

Children with a Grade I haemorrhage in combination with flares did not differ in their performance on the neurological Examination or any of the perceptuo–motor measures when compared to children without lesions. In contrast, children with a combination of a Grade IIa haemorrhage and flares were significantly poorer in their performance than those with normal scans on all assessments except total neurological optimality.

Combined versus isolated 'minor' haemorrhages

Performance of the combined lesion groups and those with 'minor' isolated haemorrhagic lesions on the neurological and perceptuo–motor assessments is given in Table 7.6. Without exception, the scores of the group of children with a combination of a Grade IIa haemorrhage and flares indicated that these children had most difficulty with the perceptuo–motor assessments.

Although none of the children with a combined lesion were classified as having a central motor deficit, the individual scores on the Movement ABC Test showed that 4 out of the 9 children (44%) with a combination of a Grade I haemorrhage and flares and 5 out of the 8 children (63%) with a combination of a Grade IIa haemorrhage and flares were poorly coordinated for their age (scores <15th centile). However, none of the group comparisons reached statistical significance.

Table 7.6: Neurological status and perceptuo-motor competence of children with isolated 'minor' haemorrhages and children with combined lesions (median; range).

	Isolated 'minor' haemorrhages		Combined lesions	
	Grade I (n=10)	Grade IIa (n=8)	Grade I + flares (n=9)	Grade IIa + flares (n=8)
Touwen's Exam. *total score*	38 (28-44)	41 (28-43)	39 (19-43)	36 (17-42)
ABC Test *total score*	5.25 (0-16.5)	1.25 (0-22)	3.5 (2-8.5)	7.75 (2-23.5)
VMI *standard score*	9 (5-11)	8 (6-11)	10 (5-15)	6.5 (5-10)
Griffiths form board *time to complete*	35.5 (23-63)	38 (31-98)	33 (28-68)	42.5 (30-145)
ABC Checklist *total score*	0.69 (.14-1.30)	0.64 (.48-.80)	0.86 (.17-1.44)	1.50 (.30-1.70)

^ Kruskal-Wallis oneway ANOVA: none of the comparisons significant.

Children with combined lesions versus those with flares

When children with combined lesions were compared to all children with flares (see Table 7.5 for the scores obtained by this latter group) no differences between the groups emerged on any of the assessments, perceptuo-motor or otherwise.

Associated problems

The groups of children with combined lesions did not differ from each other with respect to cognitive ability, behaviour or self-concept. Neither was there any difference in cognitive ability or self-concept when these children were compared to those without a lesion. However, it was interesting to note that the parents of children with a Grade IIa haemorrhage and flares tended to report more behaviour problems among their offspring than parents of those with normal scans ($p<.05$) although this was not corroborated by the teachers ($p>.05$).

Is the presence of ventricular dilatation at birth associated with poor perceptuo-motor performance at 6 years of age?

In the present study 7 children were classified as having ventricular dilatation which was already present at birth without any other ultrasound abnormality. It is not known whether this dilatation was preceded by an antenatal haemorrhagic or ischaemic lesion. In all cases the dilatation was insufficient to meet the criteria of hydrocephalus. To determine whether children with ventricular dilatation are at increased risk of perceptuo-motor problems they were compared to children with normal scans. The performance of the children who had shown ventricular dilatation at birth is summarized in Table 7.7.

Neurological status and perceptuo-motor competence

None of the children were classified as having a central motor deficit. However, 3 out of the 7 children obtained Movement ABC Test scores in the bottom 5th centile compared to 5 out of the 64 children without a lesion (X^2=4.64, df=1; p<.05).

Table 7.7: Neurological status and perceptuo-motor performance of children who showed ventricular dilatation at birth (median; range).

	Ventricular dilatation (n=7)
Touwen's Examination *total optimality score*	40 (32-44)
Movement ABC Test *total score*	4 (0-18)
Visual-Motor Integration *standard score*	6 (4-14)
Griffiths form board *time to complete*	37 (28-62)
Movement ABC Checklist *total item score*	0.88 (0.17-1.95)

The child with the poorest Movement ABC Test score (total score=18) was also the poorest of all children on the Visual-Motor Integration Test (standard score=4; <15th centile) and slow on the Griffiths form board (47 seconds; <15th centile). In addition,

there were 3 more children whose Visual-Motor Integration score fell below the 15th centile (compared to 4 out of the 64 children with normal scans; (X^2=11.65, df=1; p<.001) but who did not show difficulty with the items of the Movement ABC Test (total scores range 0 to 4). There was no difference in the number of children obtaining times above or below the 15th centile on the Griffiths form board (X^2=0.11, df=1; p>.05). The teachers of children with ventricular dilatation judged the three children with high Movement ABC Test scores as not very competent in school activities.

Associated problems

The short-form IQ scores of the 4 children with poor Visual-Motor Integration scores were at the lower end of the scale (81, 91, 95 and 108, respectively). In contrast, the three children with good Visual-Motor Integration scores had relatively high IQ scores (105-130). In Chapter 6 we already noted a relationship between short-form IQ scores and performance on the Visual-Motor Integration Test. Finally, ventricular dilatation present at birth was not associated with behaviour problems at 6 years.

Is the duration of periventricular densities (flares) in the neonatal period associated with perceptuo-motor competence at 6 years?

The 45 children with flares were assigned to one of three groups according to the duration of echodensities. One child had to be excluded from the analysis for this specific question because the quality of the scans was too poor to permit determination of the duration of the flares. In the first group, there were 13 children with flares which resolved within 7 days. The second consisted of 18 children with flares which extended beyond 7 days but resolved within 14 days and in the third, there were 13 children whose flares persisted for more than 14 days.

Neurological status and perceptuo-motor competence

Table 7.8 summarizes the performance of children with consistently normal scans and those with flares of various durations. Although there is obvious overlap between the groups on the total neurological optimality score, the trend towards children with longer flares showing an increasing number of minor neurological signs is clearly evident. The

Jonckheere test for ordered alternatives confirmed that across the four groups total optimality score decreased significantly as flare duration increased (J=3.71, p<.001).

Table 7.8: Neurological status and perceptuo-motor competence of children with normal scans and children with flares (median; range).

	normal (n=62)	flares < 7 days (n=13)	flares 7-14 days (n=18)	flares > 14 days (n=13)	p^
Touwen's Exam. *total score*	40.5 (24-46)	40 (31-46)	37 (20-45)	31 (12-42)	***
ABC Test *total score*	4 (0-23.5)	6.5 (1-20.5)	7.5 (0-25)	9.5 (0-27.5)	**
VMI *standard score*	9 (6-14)	8 (5-13)	8 (3-13)	7.5 (3-11)	*
form board *time to complete*	33 (22-101)	31 (23-70)	36 (27-65)	38 (26-67)	*
ABC Checklist *total score*	0.49 (0-1.62)	0.42 (.09-1.38)	0.59 (.11-1.50)	1.10 (.70-1.49)	**

^ Jonckheere test for ordered alternatives; * p<.05; ** p<.01; *** p<.001

When the 9 clusters of items contained in the neurological Examination were considered separately, only 3 showed a trend similar to that found for the overall optimality score. These clusters measured 'posture' (J=2.51, p<.01), 'co-ordination of the extremities' (J=2.79, p<.01), and 'gross motor functioning' (J=3.94, p<.001). In each case, it was the children whose flares lasted more than 14 days who stood out as being particulary deficient. The other clusters showed no group differences.

There was no child with a recognised central motor deficit among the children whose flares lasted less than 7 days. In contrast, the group whose flares lasted 7-14 days contained one child with a hemisyndrome [3] and one with a mild hemiplegia and the group with flares which lasted for at least 14 days contained three children with diplegia and one with a hemisyndrome.

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[3] *A hemisyndrome is defined here as an absence of 'hard' neurological signs but a presence of asymmetry of function upon neurological examination.*

When the total scores on the Movement ABC Test were subjected to trend analysis, an identical effect to that obtained on Touwen's Examination emerged. Increasingly poor performance was associated with increasing duration of flares ($J=2.97$, $p<.01$). Closer examination of the 8 individual items of the Test revealed statistically significant trends for all static and dynamic balance items as well as for 2 manual dexterity items (bicycle trail and threading beads).

A less strong, but nevertheless significant, trend across the four groups was found for both the Visual–Motor Integration and form board assessments. For each of these measures, children with flares lasting for more than 14 days showed the poorest performance.

Teacher's judgements of movement competence

The teachers opinions as to how well children with flares of various duration were coping with everyday school activities involving motor control were consistent with the findings on the individually administered assessments (see Table 7.8). A significant overall trend of increasing mean item score was found across the four groups ($J=2.39$, $p<.01$).

Associated problems

No significant trends across the four groups were found on the cognitive, behaviour or self–concept measures.

7.3 Profiles in comparison to premature children without lesions

As a way of summarizing the data presented in the previous sections, Figures 7.1 to 7.3 provide a graphic overview of performance on the neurological, perceptuo–motor and cognitive assessments for various groups of children with lesions. In order to facilitate comparison of performance across the measures, Z–scores were calculated using the mean and standard deviations obtained by premature children *without* brain lesions as reference points. A positive Z–score, therefore, indicates that children with a lesion performed above average relative to premature children with no lesion, while a negative Z–score indicates that the children with a lesion performed below average in comparison to their peers with no lesion.

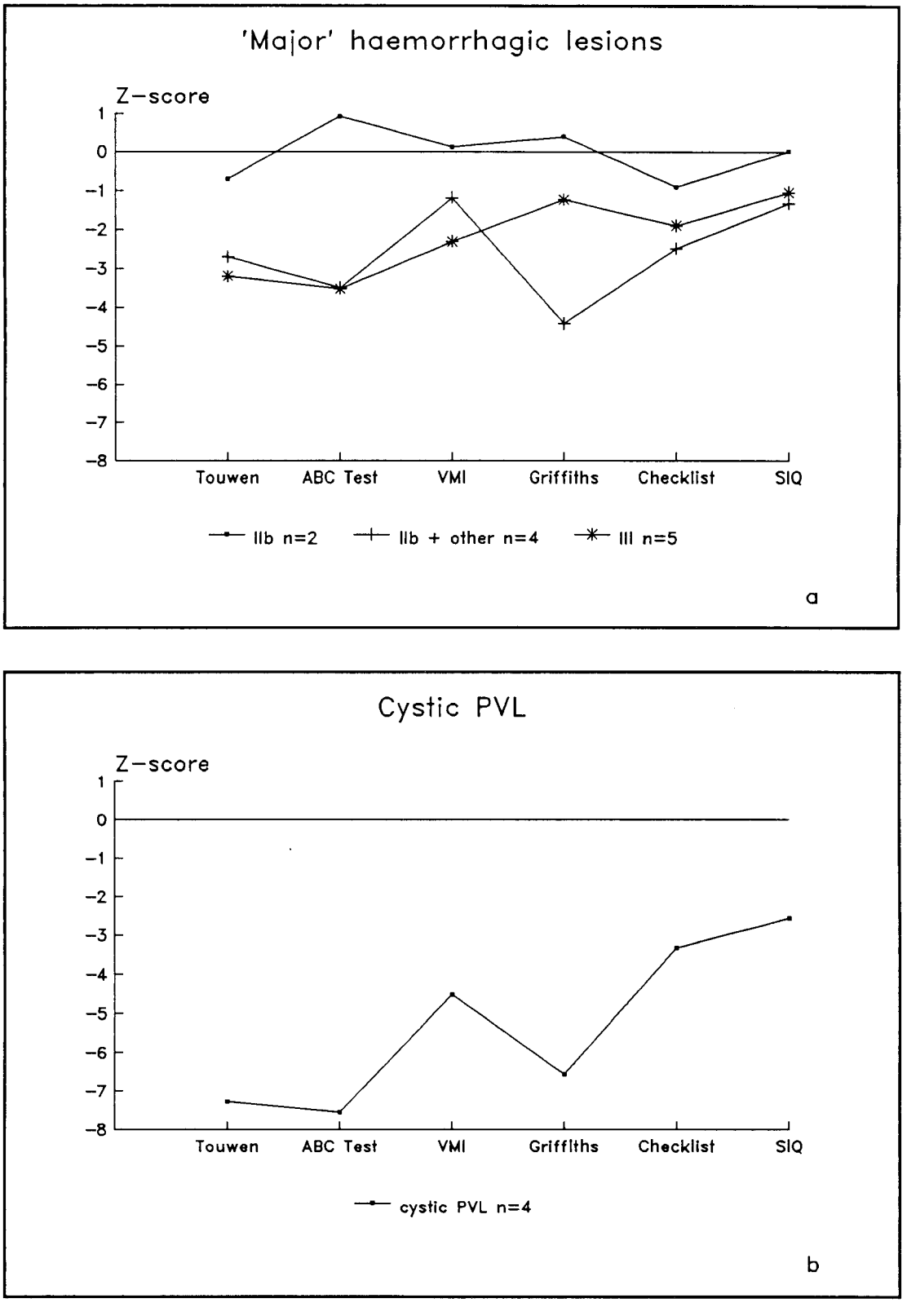
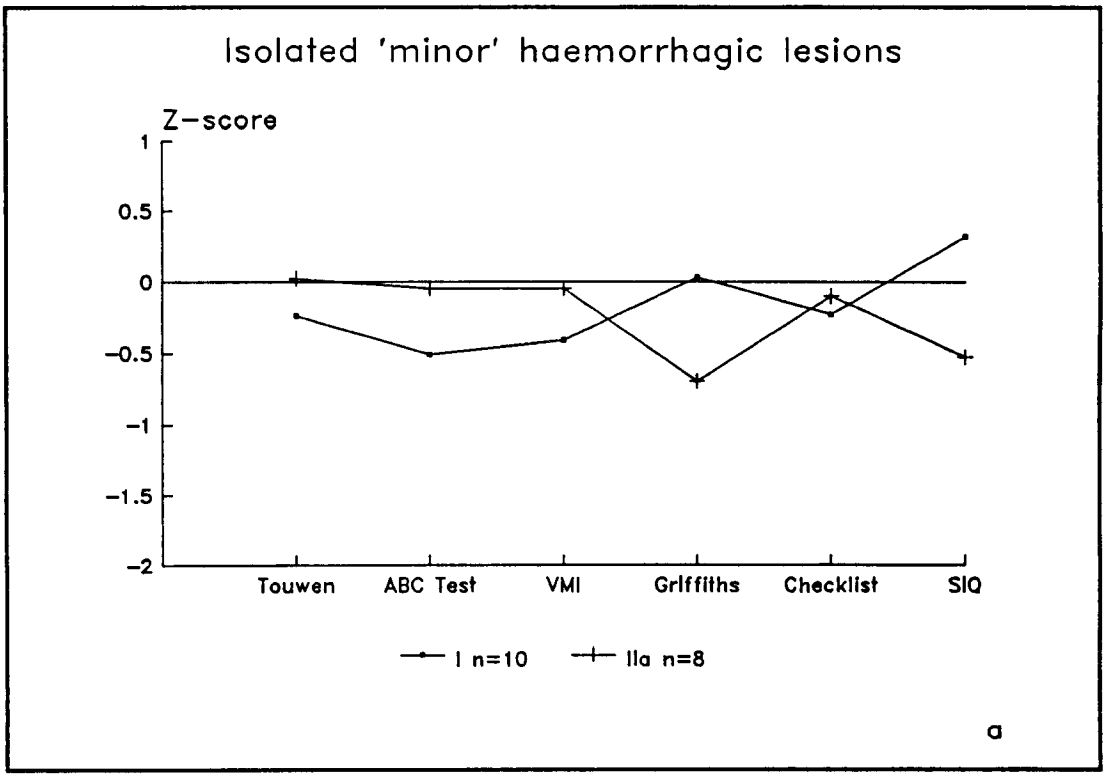


Figure 7.1: Profiles across the neurological, perceptuo-motor and cognitive assessments for children with 'major' haemorrhagic lesions (a) and cystic PVL (b).



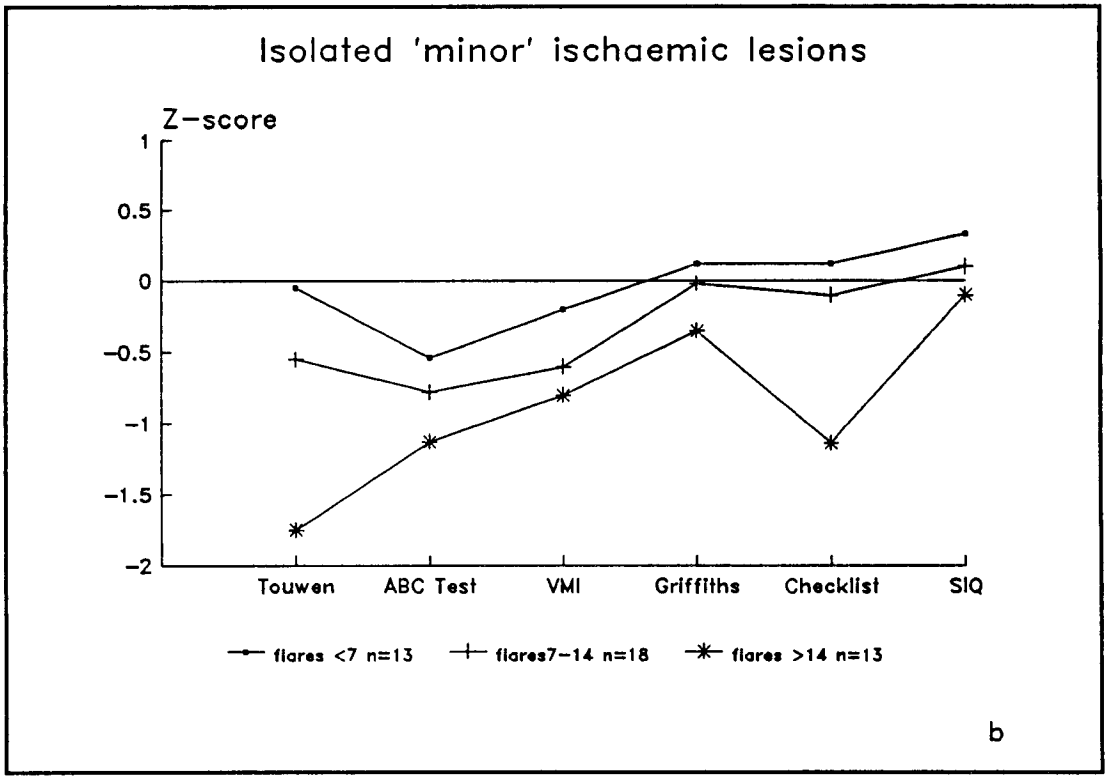


Figure 7.2: Profiles across the neurological, perceptuo-motor and cognitive assessments for children with isolated 'minor' haemorrhages (a) and 'minor' ischaemic lesions (b).

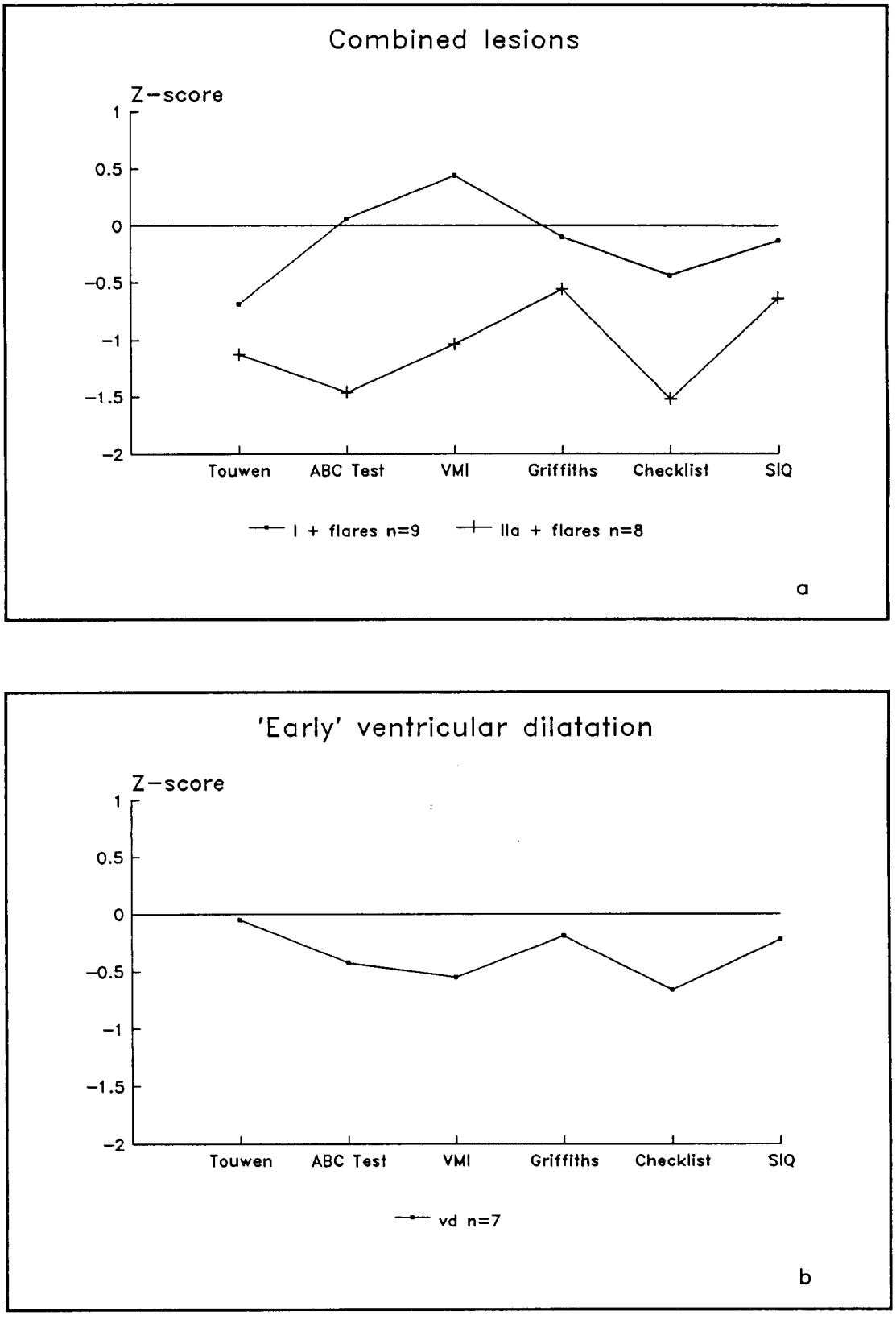


Figure 7.3: Profiles across the neurological, perceptuo-motor and cognitive assessments for children with combined lesions (a) and 'early' ventricular dilatation (b).

Children with 'major' haemorrhagic or ischaemic lesions

If we first consider Figure 7.1, it can be seen that children with cystic PVL differed from children with 'major' haemorrhagic lesions in the severity of their difficulties. While the Z-scores obtained by the 4 children with cystic PVL ranged from -7.5 to -3.0, Z-scores of children with 'major' haemorrhagic lesions ranged from +1 to -4.5. This latter group, however, seemed to fall into two groups. At one end of the scale, the 2 children with an isolated Grade IIb haemorrhage were performing closer to the mean of the of premature children with normal scans. At the other end of the scale, the diagnosis of a Grade IIb haemorrhage associated with an other brain lesions or a Grade III haemorrhage seems to lead to much more unfavourable outcome.

Isolated 'minor' haemorrhagic or ischaemic lesions

The trend noted among children with 'major' lesions was also present among children with 'minor' lesions. Children with 'minor' ischaemic lesions tend to fare less well than children with 'minor' haemorrhagic lesions. In particular, Figure 7.2b shows the consistent trends on each of the measures for children with flares of different duration. The fact that none of the groups obtained Z-scores below 2 standard deviations from the mean, however, illustrates that the problems these children experience are not as severe as those of children with 'major' ischaemic or haemorrhagic lesions. Nevertheless, it is noteworthy that none of the groups were actually better than children with normal scans (i.e. Z-scores of +2 SDs or even +1 SD). In other words, these profiles show that while the problems experienced by children with flares at 6 years of age may only be of a subtle nature, there is a consistent trend of below average performance.

Combined lesions and 'early' ventricular dilatation

Figure 7.3a illustrates vividly that the profiles of children with a Grade I haemorrhage and flares and those with a Grade IIa haemorrhage and flares deviated from each other. Although they do not seem to differ from each other with respect to the presence of minor neurological signs at 6 years of age, performance on the more functional measures of perceptuo-motor competence seem to separate the two groups well. In contrast to both these groups, children with ventricular dilatation noted at birth (Figure 7.3b) obtained neurological optimality scores that were closer to the average of that of premature children

without lesions. However, it is of interest that, compared to their performance on any of the other perceptuo-motor measures they were poorest on the Visual-Motor Integration Test.

Two general points emerge from these graphs. Firstly, the profiles illustrate variability of performance for nearly every group of children with lesions across the assessments included in our battery. For example, if we consider the pattern for children with an isolated Grade IIa haemorrhage (Figure 7.2a), it can be seen that their profile is very even across the neurological Examination and the perceptuo-motor assessments, *except* for their performance on the Griffiths form board. Although these children were not significantly slower than children without lesions on the Griffiths form board, this discrepancy is of considerable interest both from a neurological and psychological point of view. Secondly, except for children with cystic PVL, a Grade III haemorrhage, or a Grade IIb haemorrhage in combination with another lesion, the short-form IQ scores of children with lesions were close to the mean of children without lesions. In other words, there was less variability among children with 'minor' or combined lesions on the cognitive than the perceptuo-motor assessments.

7.4 Discussion

In this Chapter a number of specific questions relating to the presence or absence of neonatal brain lesions and perceptuo-motor performance at 6 years of age were addressed. In addition to comparing performance of each group of children with brain lesions to that of children without lesions, performance of various individual groups of children with lesions was also compared on the basis of the findings and hypotheses presented in previous studies.

Absence of ultrasound abnormalities

From the combined neurological and perceptuo-motor data it can be concluded that premature children with normal scans are unlikely to develop a central motor deficit and generally reach a higher level of competence at 6 years of age than their peers with an abnormal ultrasound scan. Nevertheless, there were noticeably more children who were displaying 'clumsiness' on the Movement ABC Test. In contrast, their performance on the

more perceptually loaded fine motor tasks such as the Visual-Motor Integration Test and the Griffiths form board indicated that these children are comparable to reference children. Whether this pattern of performance is reliable should be investigated in future studies.

As far as cognitive problems are concerned, the premature children with normal scans were of significantly lower cognitive ability than the reference children. This is consistent with the findings reported by Sostek (in press) and Costello et al. (1988) but in contrast with those presented by, for example, Levene et al. (1992) who did not report significant differences in cognitive ability between premature children without lesions and their matched classroom peers. Similarly, whereas the present study and that of Costello et al. (1988) did not find these children to show more behaviour problems, Fawer and Calame (1991) and Sostek (in press) did.

'Major' haemorrhagic and/or ischaemic lesions

As it is well documented that severe parenchymal echodensities which break down into extensive cystic lesions (periventricular and subcortical leukomalacia) are almost invariably followed by severe motor deficit (Graham et al., 1987; Stewart et al., 1987) it was not surprising that many children with both 'major' ischaemic or haemorrhagic lesions in our cohort developed a central motor deficit. However, these groups differed in the nature and severity of their motor deficits and the extent of associated cognitive deficits. Due to the severity of their cognitive and sensory deficits, only a few children with 'major' *ischaemic* lesions could be assessed at 6 years. In contrast, all but one surviving (blind) child with a 'major' *haemorrhagic* lesion was able to complete most components of our test battery.

Although all children were classified as having a central motor deficit, there was great variability in perceptuo-motor competence among the children with 'major' ischaemic lesions. None of the 4 children with cystic PVL were able to engage in gross motor activities such as the ball skills or balance tasks but they all attempted to complete items involving the arms and hands. In particular, one boy stood out as being relatively proficient on the manual dexterity and constructional tasks. As mentioned before, he was the only child with extensive cystic PVL whose visual acuity scores were appropriate for

his age.

It was interesting to note that among the children with 'major' haemorrhagic lesions those with a Grade IIb haemorrhage in isolation did not develop a central motor deficit nor did they show any perceptuo-motor problems at 6 years of age. They were also of average cognitive ability. However, an ischaemic insult in addition to a Grade IIb haemorrhage changed the pattern of outcome considerably. Both children with this 'combined' lesion pattern had a central motor deficit although their individual perceptuo-motor and cognitive abilities varied enormously. Among the 6 children with a haemorrhage extending into the parenchyma (i.e. a Grade III haemorrhage), 4 developed a hemiplegia and one child was also blind. Although the other 2 did not show any signs of a central motor deficit they were still poorly coordinated for their age.

In summary, the clinical picture we found among children with extensive cystic PVL and a parenchymal haemorrhage largely confirms that described by Volpe (1992). Due to the topography of cystic PVL, i.e. the region of cerebral white matter traversed by those descending fibres from the motor cortex which subserve the lower extremities, leg function in these children is especially affected. However, as the locus of necrosis extends laterally hand function becomes increasingly involved. Also in accordance with Volpe (1992), we found that not all children with a parenchymal (i.e. Grade III) haemorrhage developed a severe motor deficit. However, if neurological impairment was detected, hemiplegia affecting lower extremities as much as upper extremities was the characteristic description. In contrast to 'major' ischaemic lesions, intellectual impairment among children with large parenchymal haemorrhages seemed less common. Indeed, 4 out of the 6 children are currently in mainstream education either with or without additional help. The visually impaired child is attending a school for the blind, and one girl is in a special unit which forms part of a mainstream school and attends 'regular' classes several times a week. None of the children with 'major' ischaemic lesions attend a normal school.

Isolated 'minor' haemorrhages

The present study has confirmed the findings of other studies that 'minor' haemorrhagic lesions do not seem to be associated with an increased risk for either perceptuo-motor or

cognitive impairment at school age. For example, Fawer and Calame (1991), Levene et al. (1992), and Marlow et al. (1989) who followed cohorts of premature children up to 5 years of age, all reported similar findings. Some caution, however, should be taken in interpreting these results as conclusive evidence of the absence of any relationship between this type of lesion and later functional outcome. The children in our cohort are still young and it could be that they only start to experience difficulties when the demands placed upon them by the environment (e.g. school) gradually increase over the next years.

Recently, Ross et al. (1992) have taken research in the development of prematurely born children with 'minor' haemorrhages beyond the usual approach of administering standardised tests. They argued that because of the subtlety of the lesion it is unlikely that a negative association between 'minor' haemorrhagic lesions and functional outcome can be demonstrated when only global measures of outcome are considered. Instead, they used models generated by animal research to design a series of experiments aimed at studying specific cognitive abilities in 10 months old infants. This study is an example of how in order to fully appreciate the association between brain injury and development, a more in depth analysis of higher level functioning may be fruitful. In the final Chapter of this thesis (Chapter 9) we will report on our own attempt to devise a task, procedure and ways of analyzing in more detail the performance of premature children on a task specially designed for this study.

A combination of a 'minor' haemorrhagic and ischaemic lesion

Our findings indicate that compared to isolated 'minor' haemorrhagic or ischaemic lesions, only children with a combination of a Grade IIa haemorrhage and flares have a less favourable prognosis. In contrast, a 'double lesion' restricted to the germinal matrix (Grade I haemorrhage) and periventricular white matter does not seem to be associated with poor performance at 6 years. None of the children with combined lesions were found to have developed a central motor deficit.

From these data it is tempting to attribute the higher prevalence of perceptuo-motor problems among children with a Grade IIa haemorrhage and flares to the fact that their haemorrhage was more extensive than children who only had a lesion in the germinal

matrix. However, duration of flares may play an equally important role as was also shown in this Chapter. Among the 9 children with a combination of a Grade I haemorrhage and flares 3 children showed flares for less than a week, 3 showed flares between 7 and 14 days, and a further 3 showed flares which persisted for more than 14 days. Due to an associated ventricular dilatation (either transient or persistent) in most cases, the neonatologist who classified the ultrasound scans thought it was not valid to make a statement about how long the flares had lasted among children with a mixture of a Grade IIa haemorrhage and flares because this dilatation could have masked the presence of flares. Therefore, although we could not establish this from our data, there is a possibility that a more extensive haemorrhage is associated with a longer period of echogenicity in the white matter surrounding the lateral ventricles. Indeed, in the present study there was some suggestion that the level of perceptuo-motor functioning at 6 years of age among children with a mixture of a Grade IIa haemorrhage and flares closely resembled that of children in whom flares were observed for at least 14 days. These two groups invariably showed the worst perceptuo-motor performance out of all children with 'minor' lesions.

Ventricular dilatation present at birth

In the present study it was not possible to make a direct comparison between perceptuo-motor performance of children whose ventricular dilatation was present at birth and those who gradually developed an enlargement of the ventricles as an end-product of a previously identified lesion. Nevertheless, our results suggest that the former condition does not put children at an increased risk for developing a central motor deficit. It may seem surprising that our findings are in sharp contrast to those reported by Costello et al. (1988). However, at the time these authors gathered their ultrasound data they only had access to a linear-array scanner (as opposed to a real-time scanner). With this technique it is difficult to detect ischaemic insults in the periventricular white matter. It is, therefore, highly likely that most of their children had actually suffered from periventricular leukomalacia. Hence, we would have expected their outcome to be worse.

None of the children with 'early' ventricular dilatation had developed a central motor deficit, but 3 out of the 7 children in the present cohort showed mild to moderate perceptuo-motor difficulties as indicated by their exceptionally high score on the

Movement ABC Test. Furthermore, 4 out of the 7 children who presented with ventricular dilatation shortly after birth showed difficulty with correctly translating visual stimuli into appropriate fine motor actions as shown by their poor performance on the Visual-Motor Integration Test. In 3 children this poor visuo-motor performance co-occurred with low short-form IQ scores but not with poor Movement ABC Test scores.

Although not completely comparable to our study, Krishnamoorhty et al. (1984) reported similar findings among 12 children who developed ventricular dilatation after a Grade II haemorrhage (as seen on CT scans). In 5 children this condition stabilised while in 7 children the severity of the hydrocephalus was such that they underwent an operation to insert a shunt. At 3 to 5 years of age, 4 out of the 5 children not requiring surgery had IQ scores below 96. One of these was diagnosed as having moderate spastic diplegia. In addition, the authors observed the presence of 'fine motor immaturities' and 'perceptual difficulties' among their small cohort. Also, detailed studies of visuo-motor performance among children with mild to severe hydrocephalus confirm these findings (e.g. Anderson & Spain, 1977).

Isolated 'minor' ischaemic lesions (flares)

The results of our study have not only confirmed previous findings that the presence of periventricular densities (flares) are associated with later movement problems in childhood but have also demonstrated that the duration of flares is an important factor associated with later outcome. It was shown that impairment is not only detectable on formal assessments conducted by an experienced paediatrician and psychologist but is also reflected in the observation made by classroom teachers. The problems ranged from an identifiable central motor deficit such as mild/moderate diplegia at the severe end of the scale to more subtle impairment.

First of all, a significant trend was found between poor performance on the neurological and perceptuo-motor measures and duration of flares. Secondly, by examining separately the various components of both the neurological and functional assessments it was demonstrated that these were most marked in relation to lower limb function. The clusters of items on the neurological Examination which showed increased impairment with

increasing duration of flares were those testing 'posture', 'co-ordination of the extremities' and 'gross motor functions'. Eleven out of the 19 items included in these clusters examine the co-ordination of legs and feet, while 4 items are concerned with hand and arm co-ordination. Similarly, in the Movement ABC Test, all the 'static and dynamic balance' items were sensitive to the effects of increasing duration of flares with 2 'manual dexterity' items showing similar trends. These findings support Volpe's (1987) suggestion that periventricular lesions close to the ventricles in regions adjacent to the trigone, such as flares, will have a greater effect on the descending cortico-spinal axons which control lower limb functioning than the more laterally placed tracts controlling the upper limb - although their anatomical proximity may produce overlap in the distribution of impairment.

Although not directly comparable, the 2 reports on the association between the persistence of flares and motor function at 5 years of age (Fawer & Calame, 1991; Levene et al., 1992) show marked similarities to the findings of the present study (the inclusion of infants who had both flares and IVH/PVH makes comparison with Fawer and Calame's study more difficult). While Levene et al. did not show statistically significant differences in perceptuo-motor function between children with normal scans and those with 'prolonged' flares, both studies demonstrated that children whose flares lasted for more than 14 days were the most likely to be impaired. In the present study, we have obtained a similar outcome. By examining the duration of flares in more detail, we have extended De Vries et al.'s (1988) finding that even children whose flares last less than 14 days are at a risk for developing subtle movement difficulties.

Our findings would suggest that the previous policy of grouping children with flares which last for less than 14 days together with those who have normal scans may be misleading from both a practical and a theoretical viewpoint. At a practical level, our data suggest that it would not be safe to consider children with flares which last less than 14 days as free from risk, particularly as their impairment might affect their every-day life activities. At a theoretical level, we need further studies to achieve a better understanding of the possible effect of transient periventricular lesions on development.

Profiles

In Chapter 2 of this thesis we criticised earlier follow up studies for the limited amount of information they provided on perceptuo-motor performance of premature children. Although the documentation of incidence values of major and minor impairments and outcome on global measures are important for auditing and screening purposes, we feel that it is equally important to consider a more in depth analysis on performance across a variety of perceptuo-motor assessments. The current Chapter showed an example of a simple approach in which strengths and weaknesses in perceptuo-motor competence in relation to the type and extent of lesion could easily be demonstrated. This approach not only confirmed the observations often made by clinicians that the severity of the problems faced by children can differ across various perceptuo-motor tasks, but also showed that these can be quantified. Although this may seem an obvious observation, so far there have been few attempts in the literature to highlight these discrepancies. For example, a closer look at the profiles of children with extensive PVL show that they were relatively less impaired in their ability to produce correct copies of geometric shapes than their ability to insert the same sort of shapes in a form board though both require control of the hands. It is this type of observation which could be the starting point of further research, for example into the quality and variability of shape recognition/discrimination related to required speed of performance in children with a central motor deficit.

CHAPTER 8

Perceptuo-motor problems : a search for sub-groups

8.1 Introduction

At various points in the previous Chapters extreme variability in perceptuo-motor performance among the prematurely born children has been noted. The range of scores on the measures showed that while some premature children were as well coordinated as their randomly selected peers, others performed significantly less well. The focus of the present Chapter is on the performance of individual or small sub-groups of premature children across the perceptuo-motor tasks, irrespective of their neonatal history. The aims are to 1) sub-divide children with perceptuo-motor problems into groups which share similar profiles of performance within the neurological and perceptuo-motor domain, and 2) establish other characteristics of these sub-groups of children with perceptuo-motor problems.

Method

Subjects

Since the focus of the present Chapter is on mild to moderate perceptuo-motor difficulties (Developmental Coordination Deficit; DCD) as defined by DSM III-R (1987) this excludes the 26 children diagnosed as having a central motor deficit. In addition, the one girl who had a severe visual impairment which prevented her from completing the assessments was excluded. Therefore, a total of 156 children will be included here.

Statistical procedures

As discussed in Chapter 3, several statistical techniques have been employed in the past to arrive at sub-groups of children with perceptuo-motor problems. In the present study a four-step approach is taken.

Step 1 has already been described in Chapter 6 and consisted of identifying those children with a perceptuo-motor problem at 6 years of age by means of examining total scores on the 4 main assessments.

Step 2 consisted of 2 logistic regression analyses. The aim of the first analysis was to establish how well the complete battery of neurological and perceptuo-motor items administered in the present study was able to correctly classify children with or without

perceptuo-motor problems as determined in step 1. The second regression analysis used a stepwise procedure to identify a subset of perceptuo-motor items that were good predictors of whether or not a child had perceptuo-motor problems. In other words, the objective at this stage was to look for a shortened list of items which were most sensitive to detect differences between the groups. The results of the analyses are presented in the form of a model, which comprises those perceptuo-motor items which collectively explain outcome best. The given B's are the parameters representing the effect of individual variables on the risk of deviant outcome; the Odds ratios (OR; e^B) indicate relative risks adjusted for the effects of all other variables in the model.

In **step 3**, principal components analysis (with varimax rotation) was performed on all perceptuo-motor items to identify the relation between the items. This technique computes items that are correlated with one another but largely independent of other subsets of items and combine them into factors. These factors are thought to reflect underlying processes that have created the correlation among items (Tabachnick & Fidell, 1989).

Finally, in **step 4**, a series of cluster analyses were performed to group together the children with perceptuo-motor problems on the basis of profile similarities across the tasks. In other words, to sort the observations into groups so that the degree of association was high between members of the same group and low between members of different groups. A variety of hierarchical techniques were tried, including complete linkage (furthest neighbour), average linkage between groups, centroid and Ward's method, all based on squared euclidean distances. The rational for including items in the cluster analyses will be given in the result section.

8.2 Results

8.2.1 Identification of children with perceptuo-motor problems

As described in Chapter 6, premature children whose scores on one or more of the 4 main assessments fell below the 15th centile of the distribution of scores obtained by the reference children were regarded as having a perceptuo-motor problem. In this way, 100 out of the 156 children without a central motor deficit and/or sensory impairment were

identified as showing perceptuo-motor problems, leaving 56 children who did not show any evidence of perceptuo-motor impairment.

8.2.2 Which perceptuo-motor items separate children with/without problems best?

To determine which of the **items** in our test battery separated the children with perceptuo-motor problems best from those without perceptuo-motor problems 2 logistic regression analyses were run.

Items included in the analyses

The items of 4 clusters from Touwen's Examination which require perceptuo-motor control entered the analyses. They were: 'co-ordination of extremities' (5 items), 'fine manipulative ability' (3 items), 'gross motor function' (6 items) and 'balance of trunk' (4 items). The items of the remaining 5 clusters of Touwen's Examination were not included as they were designed to tap distinctly different behaviours such as reflexes, posture, dyskinesia, quality of motility and associated movements. Although, as discussed in Chapter 3, these are either important prerequisites for smooth performance (e.g. correct posture) or indicators of dysfunction (e.g. dyskinetic movements), these items are as such not regarded as perceptuo-motor tasks in the present study.

For the Movement ABC Test, the raw scores on the manual dexterity (3 items), ball skills (2 items), and static and dynamic balance (3 items) were retained for the statistical procedures. In addition, the standard score on the Developmental Test of Visual-Motor Integration, and the time to complete and errors made on the Griffiths were examined. In sum, a total of 29 items were considered for analysis.

Outcome

Firstly, to investigate how well the 29 individual perceptuo-motor items were able to discriminate between the two groups of premature children a logistic regression analysis was performed in which all items were forced to enter the model in a single step. All together, when using the 29 dependent variables 94% of children were classified correctly (89% of children without and 97% of children with perceptuo-motor problems).

Secondly, a stepwise logistic regression analysis was performed to determine which sub-

set of items were the best predictors of group membership, i.e. perceptuo-motor problems present or absent. The model which emerged from the analysis indicated that a combination of 7 items contributed significantly to the discrimination between the two groups. They are summarized in Table 8.1.

Table 8.1: Stepwise logistic regression: Items significantly predicting perceptuo-motor problems at 6 years of age.

Step	Item	Value label	Coefficient (B)	Odds ratio (e^B)
1	one-leg balance (Touwen)	pass=0 fail=1	2.55	12.81
2	Griffiths form board (time to complete)	range: 22-101	0.18	1.20
3	rolling ball (Movement ABC Test)	range: 2-10	-0.73	0.48
4	bicycle trail (Movement ABC Test)	range: 0-12	1.17	3.22
5	walking tip-toe (Movement ABC Test)	range: 3-15	-0.63	0.53
6	finger-tip touching (Touwen)	pass=0 fail=1	2.28	9.78
7	posting coins (Movement ABC Test)	range: 14-54	0.28	1.32
	Constant		0.3	

The item that entered the analysis first was the one-leg balance item from Touwen's neurological Examination, followed by time taken to complete the Griffiths form board, number of successful attempts to roll a ball into a goal, number of errors on the bicycle trail, number of successive steps while walking on tip-toes along a line, finger-tip touching and, finally, the number of seconds taken to post the coins into the money box. No other items contributed significantly to the separation between premature children with or without perceptuo-motor problems. Altogether, these 7 items were able to classify 85% of children without and 93% of children with perceptuo-motor problems correctly (overall 90%).

8.2.3 The relationship between perceptuo-motor items

To investigate which of the perceptuo-motor items formed coherent, relatively independent subsets, principal components analysis was performed among children with perceptuo-motor problems. This analysis was applied for two reasons. First, as a means of exploring the data and providing a tool for grouping the perceptuo-motor items. Secondly, to select from these subsets certain items to be included cluster analyses to be described later.

Before a principal components analysis can be undertaken a check must be made for 'outliers' among the total item set. Outliers, defined as items which produce very uneven splits between categories must be excluded from the analysis because their inclusion tends to decrease the correlations between items (Tabachnick and Fidell, 1989). Using Tabachnick and Fidell's suggested exclusion criterion of a 90% - 10% split, a total of three items from Touwen's Examination had to be deleted. In other words, this meant that on three items, less than 10% of the premature children failed at 6 years of age. These items were: following an object with eyes and hand, the Romberg sign, and walking on tiptoe. The first two items are from the 'co-ordination of extremities' cluster, while the last item was included in the 'gross motor function' cluster. Note that these items were <u>not</u> among the 7 reported in the previous paragraph which discriminated best between children with or without perceptuo-motor problems.

The principal components analysis of the remaining 26 items identified 10 factors which together accounted for 67% of the variance. Varimax rotation was used and, following the recommendation of Tabachnick and Fidell (1989), the cut-off level for including an item in the factor was a loading of .40 to improve the interpretability of the factors which emerged. The greater the loading, the more the item is a 'pure' measure of the factor. As can be seen from Table 8.2, 22 items loaded on one factor and 4 items loaded on two factors. Because these latter 4 items loaded on two factors they are thought to be much more complex than the 'pure' items which correlated with only one factor. The squared multiple correlations of the factor scores were on average 0.67 indicative of the strength of the linear association among the items and of the stability of the factor solution. The 10 factors with eigen values > 1 and loadings greater than .40 are presented in Table 8.2.

Table 8.2: Rotated factor loadings for principal component analysis (n=100).

factor	1	2	3	4	5	6	7	8	9	10
Touwen's neurological Examination										
response to push										.84
walking on line						.78				
finger-nose								.75		
diadochokinesis			.55		.43					
knee-heel	.60									
kicking hand	.59									
fingertip touch										.44
finger opposition			.78							
circle	.66									
follow-a-finger			.61							
heel-toe gait						.51				
walking on heels	.63									
one-leg balance		.70								
hopping	.46						.44			
sitting-up							.82			
Movement ABC Test										
bicycle trail		.56								
posting coins									.70	
threading beads .		.44							.41	
beanbag catching					.69					
rolling ball					.77					
one-leg balance		.81								
jumping over cord								.66		
walking tip-toe					.48					
Visual-Motor Integration										
standard score				.44		.46				
Griffiths form board										
time to complete				.83						
errors made				.82						

Factor 1: The items which loaded strongly on this Factor (15.6% of total variance) all came from Touwen's neurological Examination: the knee–heel test and kicking the hand of the examiner from the 'co–ordination of extremities' cluster, walking on heels and hopping from the 'gross motor function' cluster, and the circle test from the 'fine manipulation' cluster. The majority of items involved action of the lower extremities [1].

Factor 2 (9.1% of total variance) consisted of 3 items from the Movement ABC Test, 'bicycle trail', 'threading beads' and 'one–leg balance' and the 'one–leg balance' item from Touwen's Examination. The finding that the identical static balance items loaded on the same factor indicates the stability of performance of the children on this perceptuo–motor item. This second factor, therefore, showed a mixture of balance and manual dexterity items.

Factor 3: The 3 items which loaded highest on this Factor (7.4% of total variance) again all came from Touwen's neurological Examination. They involved dexterity of the fingers and hand: diadochokinesis, finger opposition and follow–a–finger. The latter two items were included in the 'fine manipulation' and the first in the 'co–ordination of extremities' cluster.

Factor 4 was an interesting factor (6.1% of total variance). It included performance on the Visual–Motor Integration Test and the Griffiths form board. Since none of the Movement ABC Test or Touwen items loaded on this factor it seems that the shape copying and form board items measure different abilities involving more highly complex visual discrimination. Our justification for including these items in our test–battery, i.e. in order to extent the range of perceptuo–motor tasks, was therefore supported.

Factor 5: The two items which most strongly loaded on the fifth Factor (5.9% of total variance) were both ball skills items from the Movement ABC Test; 'catching a bean bag' and 'rolling the ball into the goal'. This suggests that ball handling skills share a common underlying ability and that their inclusion as a separate entity in the Movement ABC Test seems justified. Two other items, diadochokinesis and walking on tip–toe also loaded, although less strongly, on this factor.

Factor 6: Two of the 3 items which loaded on this Factor (5.4% of total variance) again

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[1] *The failure of this factor analysis to confirm the clustering of items as initially proposed by Touwen (1979) is discussed in a paper by Schoemaker et al. (submitted).*

involved the lower extremities: walking on a line and heel-toe gait (both from Touwen's Examination). In addition, performance on the shape copying test was correlated with this factor.

Factor 7 (4.8% of total variance) only consisted of 2 items which both were included in the 'gross motor function' cluster of Touwen's Examination: hopping on one leg and sitting up without help of hands. It could be hypothesised that this factor reflects 'fitness' or 'muscle power'.

Factor 8 (4.5% of total variance) proved to be difficult to interpret. Both the finger-nose (Touwen's Examination) and 'jumping over a cord' item (Movement ABC Test) loaded strongly on this factor.

Factor 9: Two of the 3 manual dexterity items of the Movement ABC Test made up this Factor: 'posting coins in the money box' and 'threading beads' onto a string (4.1% of total variance). Both items involve actions which need to be accurate (i.e. putting a coin through a narrow slot and threading a string through a narrow hole) and they are performed under time pressure.

Factor 10: The 2 items which loaded on the last factor (3.9% of total variance) formed again an unexpected and difficult to interpret combination, like those in Factor 8. Response to push (Touwen's Examination) was most strongly loaded on this factor followed by fingertip touching.

In sum, the 26 perceptuo-motor items among the 100 premature children with problems could be reduced to 10 components. From a purely intuitive point of view, 8 of these seemed to 'make sense' in terms of possible underlying mechanisms of perceptuo-motor control. In contrast, there was no very obvious explanation for the other 2 Factors. In all, this factor structure suggests that several distinct processes of perceptuo-motor functioning could be extracted. For example, Factor 4 clearly indicated a connection between performance on the shape copying task and the form board task which was separate from, for example, the items included in Factor 1 which mainly consisted of items involving action of the lower limbs.

8.2.4 Sub-groups of children with perceptuo-motor problems

Having looked for cohesion among the 26 items used in our study, we now turn to the

question of whether such cohesion might be present among the children. In other words, the objective of this phase was to explore the possibility that different groups of children showed different profiles.

To address this question, the strategy adopted was as follows. First, an important issue in cluster analysis is the selection of items: it should include a minimal number of items whilst still allow for a variety of hypothesised sub-groups. Our choice of which items to include in the cluster analysis out of the total pool of 26, was partly influenced by the outcome of the regression and factor analyses. Also, we wanted to take theoretical issues into account.

It was decided to enter 6 items in the analyses. First, as described in Chapter 3, various studies have found fine motor skills to group together in factor analysis (e.g. Rarick et al., 1976; Hoare, 1991). As such, it would appear to be logical to consider some subset of these items for the analyses. Two fine motor skills (both from the Movement ABC Test) were chosen; 'bicycle trail' and 'posting coins' to represent accuracy and speed of hand movement, respectively. Bicycle trail performance had been shown to be a good predictor of perceptuo-motor impairment while posting coins (together with another timed manual dexterity item, 'threading beads') formed a separate factor in the principal components analysis.

Second, the 'rolling the ball into the goal' item from the Movement ABC Test entered the analyses. This ball skill item came out as one of the 7 perceptuo-motor items which separated children with and without perceptuo-motor problems best and had the highest loading of the ball skill items in the principal components analysis. Furthermore, it would allow for the possible sub-group of children who are less likely to be proficient in sports and games involving handling of a ball which forms an important part of physical education lessons and spontaneous play among children of this age.

Third, it was decided to include 2 balance items in the cluster analyses. Some studies have found static and dynamic balance tasks to group together in factor analysis (e.g. Krus et al., 1981; Rarick et al., 1976; see Chapter 3). However, the principal component analysis in the present study indicated a separation of these balance abilities in our cohort. Therefore, both the 'one-leg balance' and 'walking on tip-toe over a line' items from the

Movement ABC Test were included in the cluster analyses. The one-leg balance of the Movement ABC Test was preferred to that of the one-leg balance item of Touwen's examination because it has a wider spread of scores.
Finally, as described in Chapter 2, various studies (including the present one) have found premature children to perform poorly on shape copying tasks. As then described in Chapter 3, poor drawing ability has been suggested by some researchers as a possible characteristic of children with 'constructional dyspraxia' (Miller, 1986). Other expressions of this impairment are thought to be difficulties in assembling form boards or block designs. Therefore, to represent a hypothetical construct of 'constructional dyspraxia', time to complete the Griffiths form board was included. This item was preferred to the score on the Developmental Test of Visual-Motor Integration because it was a good discriminator of perceptuo-motor impairment and had the highest loading on Factor 4.

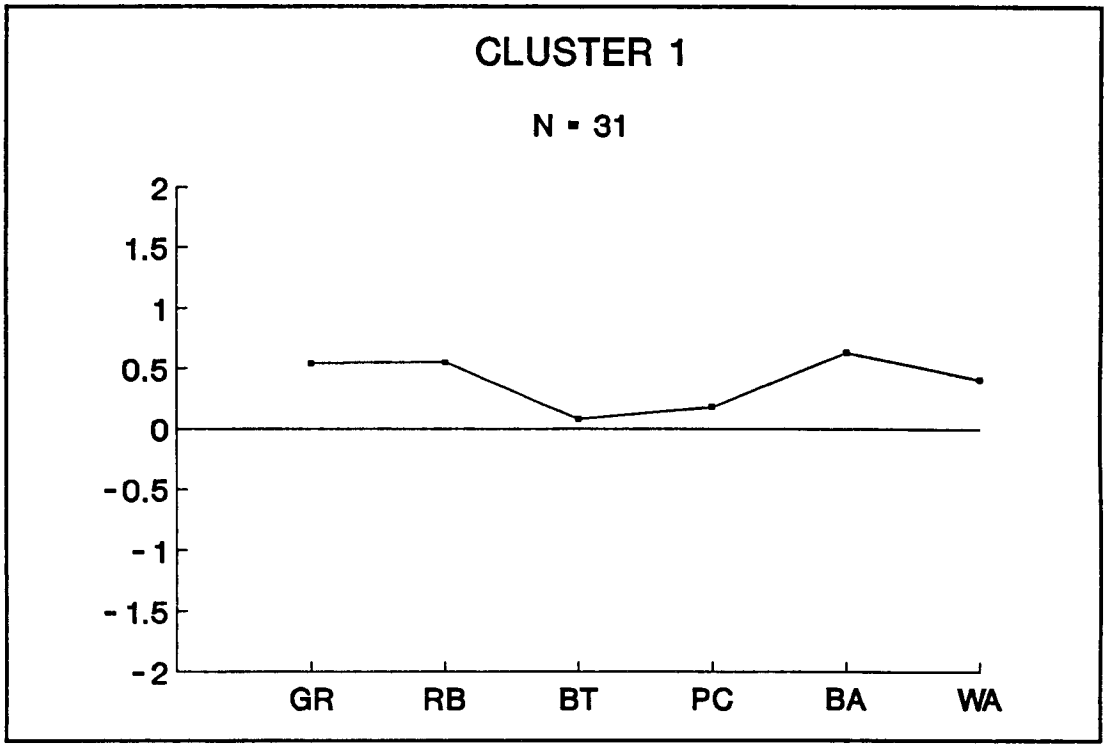
After choosing these 6 items the data were checked for children whose scores were more than 3 standard deviations away from the mean on any of the 6 items (Tabachnick & Fidell, 1989). Ten children were found and they were all removed from the subsequent cluster analyses as 'outliers' have been found to distort clusters. However, since it is the objective of this Chapter to consider the performance of all individual children, the profiles of these 10 children are presented in Table 8.3 in the form of Z-scores standardised against the group means of premature children with perceptuo-motor problems. In addition, for the sake of simplicity, the signs have been changed in such a way that a minus sign before the Z-score always indicates poor performance on the item.

As can be seen from Table 8.3, 3 children took an extremely long time to insert the shapes of the Griffiths form board. Otherwise, their performance on the remaining perceptuo-motor items was average or slightly above average. A further 3 children were characterised by the great number of errors they made on the 'bicycle trail' of the Movement ABC Test and their relative poor ability to balance on one-leg. Three more children showed extreme difficulty with the 'posting coins' item. For one child, slowness on the posting coins item was accompanied by a poor static balance performance. Finally, one child had great difficulty maintaining balance while walking on tip-toes over a line. In addition, this child exhibited poor ball skills.

Table 8.3: Z-score profiles of 10 children who were deemed 'outliers' (3 SD) and were not included in the cluster analyses.

Ss	Griffiths form board	rolling ball	bicycle trail	posting coins	one-leg balance	walking tip-toe
1	**-3.45**	1.28	-0.47	0.41	0.89	0.61
2	**-3.52**	1.28	-0.47	0.19	0.89	0.61
3	**-3.71**	-0.05	0.41	0.63	-0.14	0.61
4	0.55	0.83	**-4.39**	-0.03	-2.10	0.61
5	-0.40	-0.94	**-3.08**	-0.59	-1.48	0.61
6	-0.40	-0.05	**-4.39**	-0.14	-1.79	-2.13
7	0.68	-0.05	0.84	**-3.25**	0.89	0.61
8	-0.08	0.39	0.84	**-3.69**	-2.31	0.61
9	0.62	0.39	0.41	**-7.80**	-0.14	0.61
10	0.55	-1.82	0.84	-0.03	0.68	**-3.04**

Cluster analyses on the remaining 90 children using different hierarchical techniques revealed that 6 clusters could be identified among the data set. Results were best described by using the Ward method of clustering. This method initially considers each subject to be a cluster. At each stage of the iterative procedure 2 clusters are merged to form a new one. These 2 clusters are selected in such a way that their merger contributes least to the total within-group error sum of squares, a measure of cluster homogeneity. This process continues until all subjects are merged into a single cluster (Puterman & Dunn, 1986). The 6 clusters are graphically depicted in Figures 8.1, 8.2, and 8.3. The reader is reminded that the scores of the clusters were standardised against the mean of the group of children with perceptuo-motor problems. Thus a score that is above average is only so relative to this particular group.



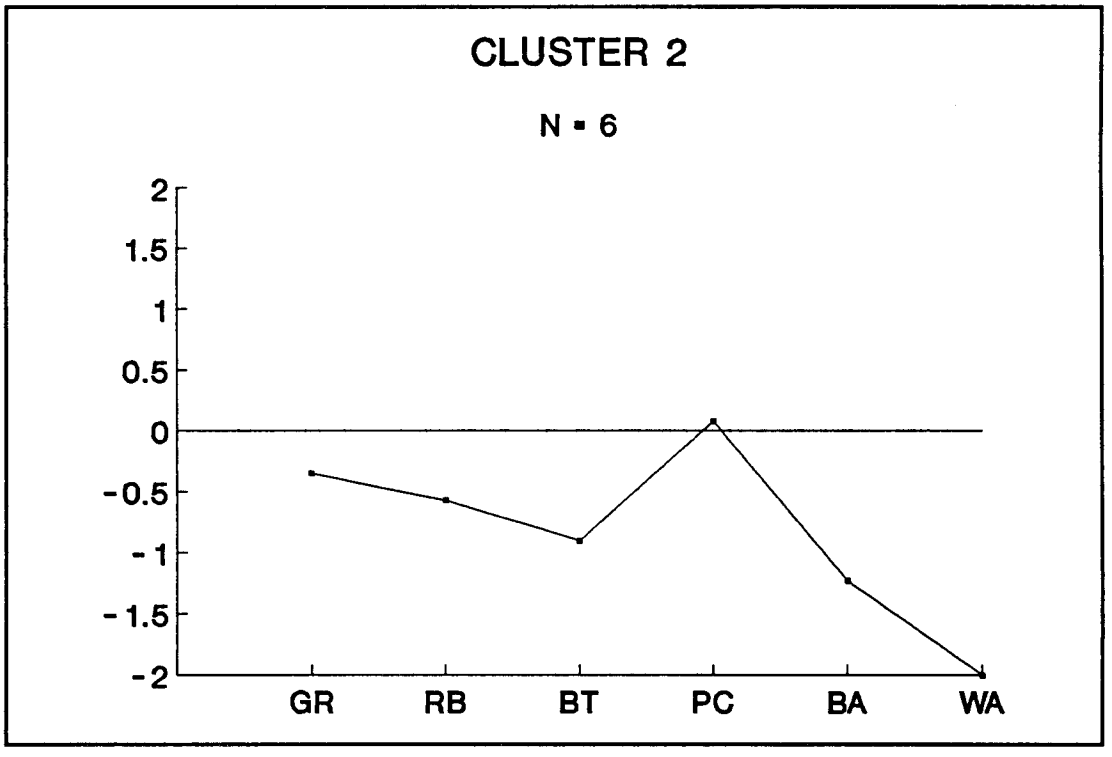
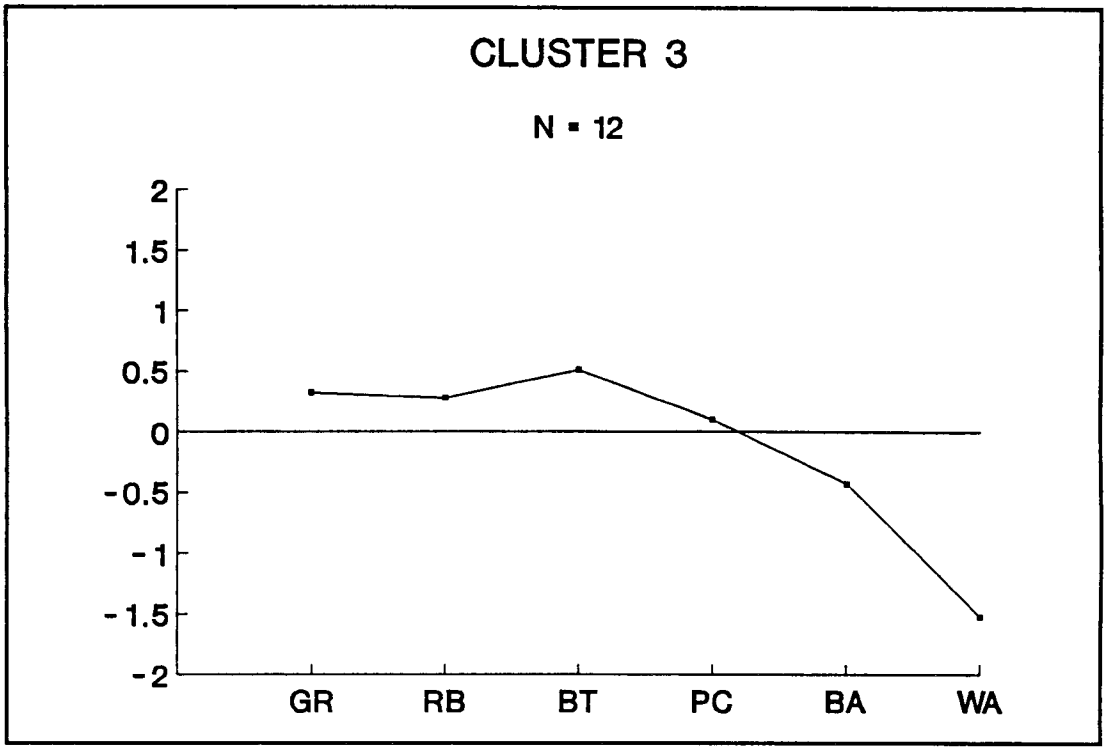


Figure 8.1: Profiles of Cluster group 1 and 2.
GR=Griffiths form board; RB=rolling ball; BT=bicycle trail;
PC=posting coins; BA=one-leg balance; WA=walking tip-toe.



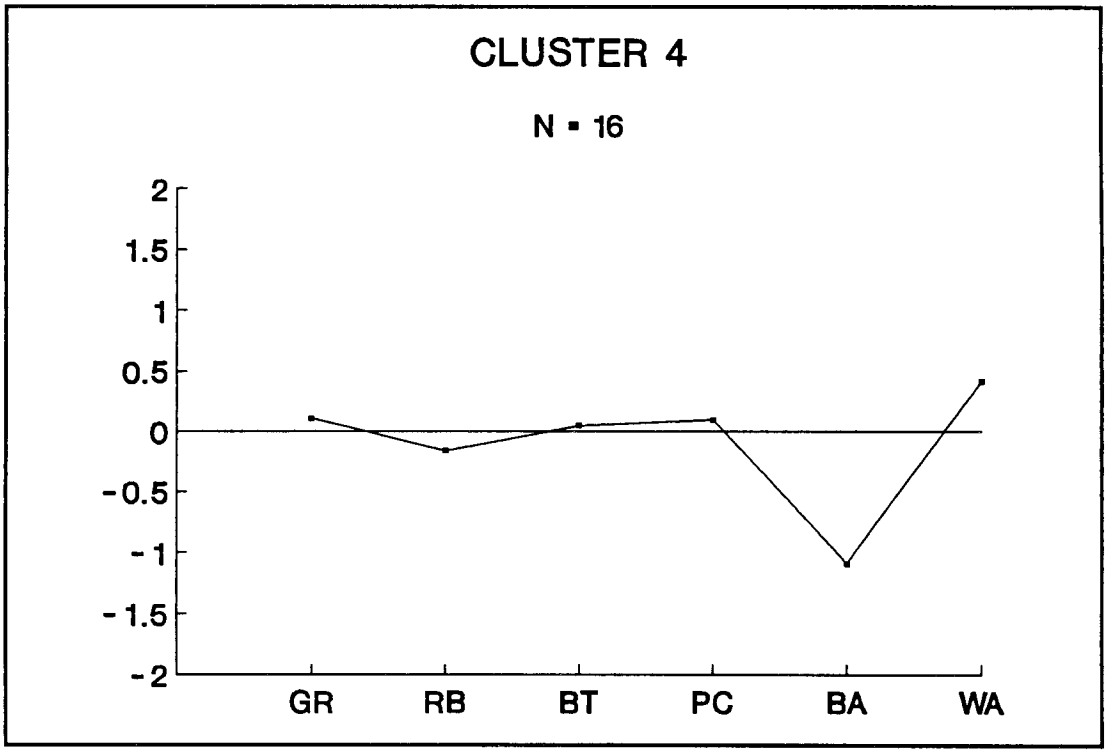


Figure 8.2: Profiles of Cluster group 3 and 4.
GR=Griffiths form board; RB=rolling ball; BT=bicycle trail;
PC=posting coins; BA=one-leg balance; WA=walking tip-toe.

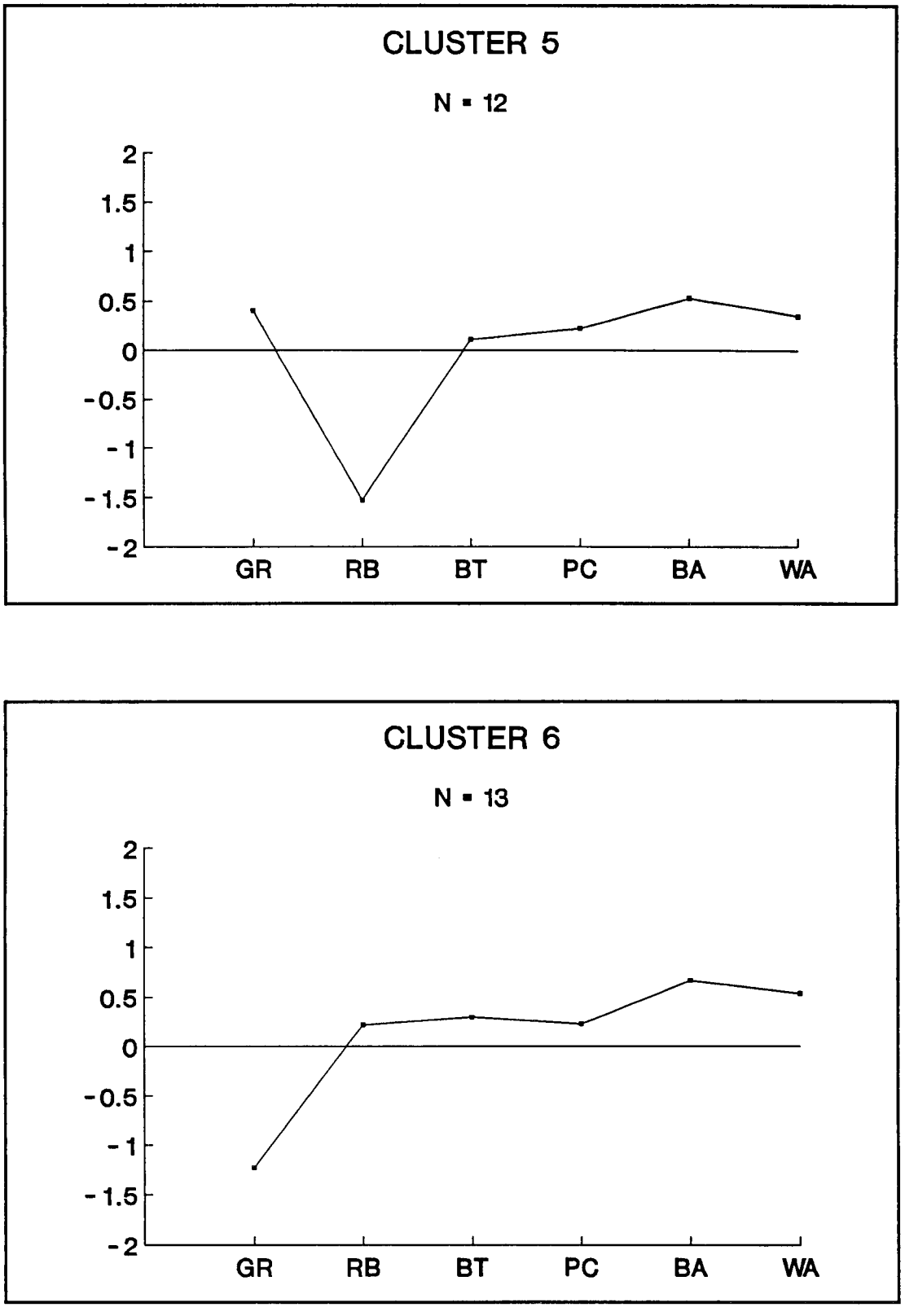


Figure 8.3: Profiles of Cluster groups 5 and 6.
GR=Griffiths form board; RB=rolling ball; BT=bicycle trail;
PC=posting coins; BA=one-leg balance; WA=walking tip-toe.

Cluster 1 had the largest membership of 31 subjects. The children in this Cluster distinguished themselves from children in other Clusters by slightly above average performance and their profile showed little differentiation between performance on the selected items.

Children in **Cluster 2** (n=6) differed considerably from those in Cluster 1. Their profile showed a consistent below average performance except on the manual dexterity item measuring speed of performance. All children in this group were boys; 3 of these were the male members of the same set of quadruplets.

Cluster 3 included 12 children. Their profile was characterised by a discrepancy in performance involving the upper and lower limbs. They showed poor dynamic balance ability (−1.52) and, to a lesser extent, poor static balance ability (−0.86). Otherwise, their performance fell above the mean.

The 16 children in **Cluster 4** stood out as having difficulty with static balance (−1.09) only. In contrast, their ability to walk along the line on their tip−toes was slightly above average (+0.42) and scores on the other 4 items were close to zero. These children, therefore, showed a more specific balance problem than the children in Cluster 3.

Cluster 5 consisted of 12 children. They stood out as being particularly poor on the ball skill item (−1.53) but proficient on the other items, noticeably their static balance ability. It was interesting to note that 10 out of these 12 children were girls.

The 14 children in the final Cluster, **Cluster 6**, showed great discrepancy between performance on the constructional item and performance on the other items. Their mean Z−score on the Griffiths form board was −1.23, while their static and dynamic balance scores were +0.67 and +0.54, respectively.

To examine the internal validity of the clusters we looked for a small sub−sample of prematurely born children whose performance on all the main assessments was above average. However, none of the 56 children who were identified as being free of perceptuo−motor problems obtained such good scores across the 4 assessments. Therefore, instead of applying the top 15th centile as a cut−off point, the criterion was changed to performance in the top 50th centile as compared to the reference children. This resulted in a small group of 7 children. When these children were added to the cluster analysis, 6 children were grouped together with those in the original Cluster 1. The other child was

added to the original Cluster 4. Although we would have expected these 7 children with (relative) consistently good performance to form a new cluster, the fact that most were grouped with the 'best' children identified as having perceptuo-motor problems was not completely surprising as none of the premature children could be rated as extremely well coordinated. In addition, 10 children identified as having perceptuo-motor problems changed cluster, a total change of 11% in cluster membership.

In sum, 6 items thought to represent accuracy and speed of hand movements, ball skills, static and dynamic balance ability, and constructional ability were selected on the basis of the outcome of previous analyses and included in analyses on sub-typing of perceptuo-motor impairment. The cluster analyses among 90 premature children with perceptuo-motor problems identified 6 sub-groups. Children in Cluster 1 and 2 showed overall good or poor performance in relation to other children with perceptuo-motor problems, respectively. The children in the remaining 4 Clusters showed more diverse profiles. Those in Cluster 3 and 4 were characterised by static and/or dynamic balance problems, while Cluster 5 and 6 represented specific ball skills and constructional problems. The profiles of 10 children which were excluded from the analyses also revealed specificity in relation to perceptuo-motor problems. These findings support the notion of a wide variety of perceptuo-motor problems among prematurely born children.

8.3 Other characteristics of sub-groups

As described in Chapter 6, children with perceptuo-motor problems tend to be of lower cognitive ability and show more behaviour problems in school than children without perceptuo-motor problems. As we have now further sub-divided the children with perceptuo-motor problems into smaller groups it is of interest to examine whether these sub-groups differ in the extent of 'associated' problems and whether they could be distinguished from each other on the basis of neonatal characteristics. Table 8.4 summarises the scores obtained by the 6 sub-groups on the Movement ABC Checklist, the cognitive ability, behaviour and self-concept measures.

Table 8.4: Teacher's judgements of competence, cognitive ability, behaviour and self concept scores of sub-groups of children with perceptuo-motor problems.

	Cluster group					
	1 (n=31)	2 (n=6)	3 (n=12)	4 (n=16)	5 (n=12)	6 (n=13)
Movement ABC Checklist (median; range)	0.69 0.10-1.95	1.61 (n=1)	0.90 0.20-1.70	0.77 0.14-1.38	0.64 0.17-1.52	0.50 0.21-1.12
BAS Short-form IQ (mean; SD)	106 11	97 10	107 16	105 14	111 12	102 11
Rutter Scale parents (median; range)	10 3-22	12 9-18	8 4-18	9 3-24	9 2-28	7 2-23
Rutter Scale teachers (median; range)	2 0-9	0 (n=1)	3 0-12	5 0-14	3 0-13	5 0-8
Self-concept Scale (median; range)						
cognitive competence	3.50 2.17-4.00	3.33 2.00-3.83	3.09 1.50-4.00	3.67 2.33-4.00	3.17 2.17-4.00	3.67 1.17-4.00
peer acceptance	3.67 2.00-4.00	3.17 3.00-3.83	3.42 2.00-4.00	3.33 1.67-4.00	2.92 2.00-4.00	3.50 1.83-4.00
physical competence	3.33 2.00-4.00	3.17 3.00-3.33	3.17 1.83-4.00	4.00 2.67-4.00	3.42 2.50-4.00	3.67 1.67-4.00
maternal acceptance	2.83 1.83-4.00	3.00 2.50-3.83	2.83 2.00-3.83	2.67 1.83-4.00	2.92 1.50-3.83	3.00 2.00-4.00

Unfortunately, the teachers of 29 children did not return the Checklist. This meant, for example, that only one child in Cluster 2 could be evaluated on this measure. His Checklist score was 1.61 which was rather high and, therefore, in agreement with our own observations. However, because no data were available on this measure for the remaining 5 children this means that it could not be established whether the judgements of these teachers were in agreement with the cluster analyses findings. No main effect of group was found (Kruskal-Wallis oneway ANOVA; p=0.17) between the other 5 Cluster groups. A closer look at the distribution of Checklist scores showed that the children in Cluster 3 obtained the highest median score (median=0.90; range=0.20-1.70). In other words, the

teachers judged the perceptuo-motor skills of children with static and dynamic balance problems as being rather poor. In contrast, children in Cluster 6 obtained the lowest (i.e. best) median Checklist scores (median=0.50; range=0.21-1.12). The favourable judgements of teachers on overall perceptuo-motor competence of these children may be due to the specific difficulty these children showed. Instead of consistent poor performance they only showed one area of impairment (i.e. constructional ability) which, although may have been noted by the teacher, was not enough to rate the child as overall poorly coordinated.

Univariate analyses showed that there were no differences between the Cluster groups on either short-form IQ scores, total Rutter parent or total Rutter teacher scores, or any of the subscores of the self-concept Scale. However, it was noted that children in Cluster 2 whose overall perceptuo-motor performance was the poorest among prematurely born children without a central motor deficit were more likely to exhibit cognitive and behaviour problems. They obtained the lowest mean short-form IQ score (mean=97; SD=10) and the highest total Rutter parent scores (median=12; range=9-18). In contrast, children in Cluster 5 whose most prominent feature was poor performance on the ball skill item were found to be of high cognitive ability (mean short-form IQ score=111; SD=12). Interestingly, the two groups of children who noted on the self-concept Scale that they felt not very competent in physical activities were those who performed poorly on all items (Cluster 2) or experienced specific difficulties with dynamic balance tasks (Cluster 3; group differences in this particular domain of self-concept approached significance p=.07).

Neonatal characteristics

There was no difference between the groups in gestational age ($F=0.46$, $df=5,89$; $p>.05$) nor did the groups differ in birthweight ($F=0.84$, $df=5,89$; $p>.05$).

The children in the various Cluster groups were compared on the presence and type of ultrasound abnormality in the neonatal period. Table 8.5 summarises these findings.

Table 8.5: Classification of ultrasound scan among sub-groups of children with perceptuo-motor problems.

Cluster group	Classification of ultrasound scan					
	Normal	Grade I/IIa haemorrhage	flares	Grade I/IIa and other	ventricular dilatation	Grade IIb (+other)/ III/Infarct
1	10	2	7	6	4	2
2	-	3	2	1	-	-
3	6	-	4	1	-	1
4	5	3	5	3	-	-
5	2	-	9	-	1	-
6	5	1	3	2	1	1
total	28	9	30	13	6	4

Generally speaking, no direct relationship emerged. All Cluster groups consisted of a mixture of children with or without brain lesions, except for children in Cluster 2. The children in this latter group had shown isolated 'minor' haemorrhagic lesions, a combination of a Grade IIa haemorrhage and flares, or flares (present for less than 14 days). Furthermore, half of the children in Cluster 3 whose profile was characterised by a discrepancy in performance on items involving the lower and upper limbs had either shown flares lasting for more than 14 days or combined lesions such as a Grade IIb haemorrhage, flares, infarct and cyst, or a Grade IIa haemorrhage, flares and infarct. Nevertheless, the other 6 children in Cluster 3 had normal ultrasound scans. Finally, in Chapter 7 we already reported that not all children with what were classified as 'major' brain lesions develop a central motor deficit. Four of these children were included in either Cluster group 1 (Grade IIb or Grade III haemorrhage), 3 (Grade IIb haemorrhage, flares, infarct and cyst) or 6 (infarct).

8.4 Discussion

The literature on perceptuo-motor competence of prematurely born children as they progress through the first years of life has focused mainly on global estimates of competence. Little attention has been paid to the variation in performance that underlies these global estimates. Yet, it is obvious that the consequence of being poor in just one area of perceptuo-motor functioning is completely different from experiencing problems

in a different or more than one area. Consider the child who simply lacks proficiency in ball skills versus the child who has fine motor problems in addition to his/her 'clumsiness' in ball skills. Although the problems both children have are likely to affect aspects of their ability to cope with the school curriculum, the cumulative problems of the latter child puts it at a greater risk for lower levels of attainment across a whole spectrum of every day school activities. In this Chapter various attempts have been made to explore this variation and consider its implications.

Predicting group membership

Before beginning any analysis of the way the items included in our assessment battery grouped together, an attempt was made to examine the strength of each individual item as a predictor of group membership. When using all items the logistic regression analysis was able to successfully classify all but 9 premature children as having perceptuo-motor problems or not (94%). Six of these children were classified by us as having no perceptuo-motor problems, while in 3 cases the opposite was true.

In the gross motor domain, the stepwise analysis showed one-leg balance to be the best overall predictor of 'clumsiness'. The strong predictive power of this item has been reported previously among children with a Developmental Coordination Disorder (DCD) by Hoare (1991) who reported that the majority of the items with the greatest discriminative power in her study ".. required primarily coordination of the lower limbs to be sustained over a period of time" (p. 166). Added to this, Johnston et al. (1987) found stationary hop, one-leg balance, heel-toe walk, jumping and bouncing a ball the 5 best predictors of poor coordination. Three of the 7 predictive items in the present study roughly correspond to these, i.e. one-leg balance, walking on tip-toes and rolling a ball into a goal.

The second most predictive item was time to complete the Griffiths form board. As no previous study has included this task as a measure of perceptuo-motor competence it is difficult to put this finding into context. However, it does suggest that this item contributes to identification of perceptuo-motor problems in children and should, therefore, be considered for inclusion in future studies. The remaining significant

predictors all involved fine manipulation tasks: bicycle trail, fingertip touching, and posting coins. These findings suggest that a small number of carefully chosen perceptuo-motor items covering fine and gross motor ability as well as more perceptually loaded tasks may be sufficient to detect the majority of poorly coordinated premature children. Future studies should be designed to explore whether this set of items is just as successful in discriminating between children with and without perceptuo-motor problems in other cohorts of children with movement difficulties.

The relationship between perceptuo-motor items

The organisation of perceptuo-motor abilities in children has been of interest to motor development researchers for many years. Factor analytic studies have been used to develop taxonomies of performance in the perceptuo-motor domain (e.g. Rarick et al., 1976). To examine patterns of perceptuo-motor performance in the current cohort of prematurely born children with problems it was decided to perform a principal components analysis to obtain an empirical summary of the data set (Tabachnick & Fidell, 1989).

Ten factors were identified with eigenvalues greater than 1. On the one hand, some of these resemble factors reported in other studies. For example, the present study identified a factor containing items involving rapid and precise movements of the hands (posting coins and threading beads). A comparable factor of 'manual dexterity' was identified by Hoare (1991) among a sample of children selected on the basis of the presence of perceptuo-motor problems between the ages of 6 and 9 years. The tasks which loaded highest on this factor in her study involved rapid and precise hand movements, i.e. total number of pegs placed in the Purdue pegboard (unimanual, bimanual and assembly), number of beads threaded on a rod, and the number of marbles transferred from one container to the other. Similarly, Hoare identified a factor which she labelled 'gross body coordination' which included several ball and locomotor skills. Except for diadochokinesis, the items loading on Factor 5 in the present study closely resembles this.

On the other hand, some factors which emerged in this study seemed more specific to our cohort. For example, the largest proportion of variance in the present study was accounted for by a clear factor of 'dynamic lower limb coordination'. The items which loaded on this

factor all came from the neurological Examination. The identification of such a strong factor may not come as a complete surprise given the fact that 44 out of the 100 children with perceptuo-motor problems had shown flares (in isolation or combined with 'minor' haemorrhagic lesions) in the neonatal period. As discussed in Chapter 7, there was a tendency for these children to be particularly poor at activities involving the lower limbs.

Finally, examining the sub-tests of the Bruininks-Oseretsky Test of Motor Proficiency, Broadhead et al. (1985) have found that the factor structure of perceptuo-motor abilities changes across age groups, showing increased differentiation as children develop. It should, therefore, be noted that the factor structure reported in this study is most likely to be age-dependent and may not generalize to younger or older children.

Sub-groups of children with perceptuo-motor problems

Administering a wide variety of perceptuo-motor tasks and using both a descriptive and statistical multivariate analysis approach, the findings of the present study have not only confirmed the earlier observed variability in perceptuo-motor performance among prematurely born children but also that it is possible to distinguish between sub-groups of children with perceptuo-motor impairment. In the present study it was decided to enter 6 items in the cluster analyses: time taken to complete the Griffiths form board, number of successful attempts in rolling a ball into a goal, number of errors on the bicycle trail, number of seconds on the posting coins task, number of seconds balanced on one-leg, and number of successive steps while walking on tip-toe. Each of these items was carefully chosen and their inclusion was justified by the supporting analyses. Nevertheless, we feel it is important to acknowledge that the choice of items influenced the cluster solution and that further empirical investigations of sub-groups among children with perceptuo-motor problems are needed to substantiate our findings.

Using the set of items 6 clusters were identified in the present study. The first Cluster group consisted of children who performed slightly above average on all items compared to the total group of premature children with perceptuo-motor problems. Their profile indicated that there were neither items on which they excelled nor were there items with which they had extreme difficulty. Cluster group 2 showed overall poor performance. A

similar Cluster group was reported by Hoare (1991; Cluster group 3). She observed that in many cases the perceptuo-motor problems of these children were accompanied by learning disabilities. As the present study did not specifically question the teachers of the children on, for example, their reading, writing and maths ability it is difficult to comment on the prevalence of learning disabilities among these children. However, their short-form IQ scores and the behaviour ratings by their parents indicate that they were the most likely to experience associated problems of all Cluster groups. It was only in this Cluster group that all children had suffered a brain lesion in the neonatal period.

The analyses conducted by Hoare (1991) revealed 4 more sub-groups of 'clumsy' children in addition to the one already mentioned above. She also chose 6 items to enter the analyses: scores on a kinaesthetic acuity test, the Motor Free Visual Perception Test, the Developmental Test of Visual-Motor Integration, number of seconds to insert pegs into the Purdue peg board, to balance on one-leg, and to run 50 metres. Because only 3 items Hoare's and in the present study roughly similar (static balance, unimanual dexterity and constructional ability), it is difficult to compare the results between the studies. However, since nearly one-third of the children in Hoare's study were born prematurely, it is of interest to report her results her.

The first and largest Cluster group identified by Hoare was best characterised by above average performance on static balance tasks while at the same time below average ability on a running task (relative to other children with perceptuo-motor problems as with all other groups). The second Cluster group distinguished itself by above average ability on visual perception and visual motor skills and slightly below average ability on a static balance task. Performance of children in the fourth Cluster group was of average or above average ability on all tasks except a visual perceptual task. The final, smallest Cluster group had particular difficulties with motor tasks rather than perceptual tasks. These results, therefore, support the notion of heterogeneity among children identified as having perceptuo-motor problems at school age and that such sub-groups can be identified reliably.

The remaining four groups which emerged from the Cluster analyses in the present study

could be described as showing specific difficulty with either 1) static and dynamic balance, 2) static balance only, 3) ball skills or, 4) constructional tasks. The mechanisms related to these abilities will be discussed in more detail below.

Implications for understanding 'clumsiness'

Postural control

One of the most frequently cited problems in prematurely born children is their inability to maintain balance (e.g. Largo et al., 1990a; Nickel et al., 1982; Vohr & Garcia Coll, 1985; Black et al., 1977). The results of the logistic regression analysis indicated that both one-leg balance and walking on tip-toes were good predictors of group membership. Furthermore, the cluster analyses showed that 2 of the 6 groups could be characterised by inability to maintain postural control. However, balance problems are not only found among prematurely born children. Studies that have described movement difficulties in children with a developmental coordination disorder (DCD) (e.g. Henderson & Hall, 1982; Johnston et al., 1987) all comment on the large proportion of children found to be unable to perform a task involving postural control in a stationary and/or moving position.

The children who were not proficient in the postural control tasks showed a wide variety of strategies in their attempt to cope with the task demands. On the one hand, there were children who tried to compensate with exaggerated movements once they lost their balance. This put them in an even more unstable position. On the other hand, there were children who did not try to compensate at all. For example, when they could no longer maintain the one-leg balance position, they simple put their other foot on the floor without trying to compensate with trunk or arm movements first to regain control. Another observation was that many children moved their eyes and head in various directions while executing the task.

Taken together, these qualitative observations underline the importance of vision, kinaesthesis and information from the vestibular receptors (which are important for monitoring the position and movement of the head), as well as other factors such as muscle power and endurance, in the postural control of movements. Numerous experiments over the years (e.g. Lee, 1978; Lee & Aronson, 1974; Shumway-Cook &

Woollacott, 1985) have shown that vision and kinaesthesis both play a major role in control of posture and locomotion. Vision provides information of objects in the environment, the lay–out of the environment and the events which take place in the environment. Kinaesthesis is the information that specifies the positions and movements of the body parts in relation to the body. In addition, Lee (1978) argued that a third source of information is needed in the control of posture. He labelled this as exproprioception: information about the environment and body in relation to each other.

The task of walking along a line on tip–toes serves as an example of how these sources of information interact. As the child is walking along the line, vision is not only used to monitor the position of the feet in relation to the line, but also to plan ahead the steps to be taken. Kinaesthesis provides information of whether the heels are sufficiently lifted from the floor, direction of the leg movements, and the position of the arms and trunk while walking. If a child, therefore, does not direct its visual attention to the line or the feet (by frequently moving the eyes and head to different directions) it is likely that this disturbs balance. Also, if kinaesthetic feedback from the position of the body is not used efficiently (either by under– or over–reacting to stimuli), correction of movements becomes difficult.

Ball skills

A different Cluster group showed specific difficulty with the 'rolling ball into the goal' item from the Movement ABC Test indicating problems with aiming tasks. As the correlation between this and the other ball skill task, i.e. catching bean bag, was 0.41 ($p<.0001$) among premature children with perceptuo–motor problems and both items appeared in the same factor, it is appropriate here to discuss the mechanisms contributing to (un)successful execution of each item.

On the rolling ball task, the most frequent qualitative observation was related to fixation of the eyes on the target. Of those children that failed the task, many did not direct their gaze at the target but instead looked at the hand releasing the ball. Controlling the direction of the ball became therefore difficult. Furthermore, instead of using a pendular swing of the arm, many children 'pushed' the ball towards the target despite a

demonstration preceding the practice trials. Due to the movements of the wrist the ball was often sent either beyond the right- or left-hand side of the goalposts. One interpretation of these observations could be that inexperience with the task made the children concentrate on only part of the task (i.e. release of ball) and that they had not yet mastered the integration of the different components of the task. Also, the fact that the majority of children identified in this cluster were female may point to the influence of culturally determined factors.

Difficulty with catching a bean bag can be associated with a number of factors such as difficulty visually tracking the bean bag and coordinating the movements necessary for a successful catch. In addition, personal observations suggested that some premature children had difficulty maintaining or adjusting their balance/posture while concentrating on the bean bag when it was in flight. This resulted in an awkward movement pattern associated with failure. For other children, however, it was noted that poor performance seemed to be related to timing of movements. Often the hands and fingers closed either too late or too early. A lack of temporal accuracy when intercepting a moving object has been found in experimental studies in which children with a DCD took part (Forsstrom & Von Hofsten, 1982; Gordon & McKinlay, 1980; Hoare, 1991).

Constructional skills

Children in Cluster 6 showed an interesting profile across the perceptuo-motor items which was characterised by poor performance on the Griffiths form board but at the same time above average performance on the fine and gross motor items. Although they were excluded from the cluster analyses, 3 more children showed a roughly similar profile (Subjects 1 to 3 in Table 8.3). It took these children so long to insert the shapes that their times to complete the task fell below 3 SDs compared to other children with perceptuo-motor problems. However, like the children included in Cluster 6, they were relatively good on other perceptuo-motor tasks.

The principal components analysis suggested that the form board task shares a common underlying mechanism of control with the shape copying task and that together they form a separate, distinct aspect of perceptuo-motor functioning. As briefly discussed in Chapter

3, the phenomenon of 'constructional dyspraxia' has been acknowledged for some time. Poor constructional abilities in children have been associated with sensory integration dysfunction (Bundy & Fisher, 1992) which has received much attention among occupational therapists. Other end products of sensory integration dysfunction are thought to be poor form and space perception (e.g. figure-ground perception) and poor visuo-motor skills (e.g. design copying).

Approximately 1 out of 5 premature children without a central motor deficit in the present study had great difficulty with the geometric shape copying task. Because this tasks requires the integration of visual and motor processes a deficit in either affects performance. Personal observations suggested that a minority of the children had difficulty with the actual motor component of the task as observed by the quality of the lines drawn (i.e. most children produced neat straight lines instead of wobbly lines), the smoothness of the movements while drawing, and a good pencil-grip in most children. Instead, the complexity of the shape in terms of its spatial orientation (e.g. as seen by the reversal of direction) and organizing the appropriate response (e.g. hesitation to continue drawing) seemed to be associated with poor performance on the copying task. Furthermore, it was observed that once having looked at the target shape, many children reproduced it without referring back to the target shape while they were drawing. In other words, continuous visual monitoring was absent. Moreover, when they had finished drawing only a few children compared their reproduction with that of the original shape. Figure copying in children with perceptuo-motor problems has been studied extensively (e.g. Abercrombie et al., 1964). In general it is thought that three problems in adequate drawing (and handwriting) can contribute to these problems: inadequate perception of the shape or letter, difficulties in translating what is perceived into a motor plan, and poor coordination in executing the plan (Sugden & Keogh, 1990). Our informal observations confirm the contribution of these components to failure on the task.

The next Chapter in this thesis will address specific questions in relation to performance of 6-year-old children (specifically those identified in Cluster 6) on two different form boards. For a discussion on the task requirements and the nature and type of problems observed in this cohort the reader is, therefore, referred to the next Chapter.

CHAPTER 9

Constructional skills – a detailed analysis of performance on a form board task

9.1 General introduction

Clinicians and researchers have long been fascinated by children who have particular difficulty with tasks which require the transformation of a complex visual input into a motor response (e.g. Abercrombie, 1964). In everyday life, these difficulties begin to manifest themselves when children are given Activity boards and Lego, and become more apparent as jigsaws, drawing and writing are introduced to them. Sometimes, difficulty with this particular class of activity is described as part and parcel of a more general perceptuo-motor impairment. At other times, it is treated as a highly specific deficit, labelled 'constructional dyspraxia'. To date, however, there have been few studies which systematically address questions related to the associations or dissociations between different aspects of perceptuo-motor development including exploration of the factors which might contribute to failure on this type of task has been limited.

Although there are numerous versions of each, the assessments psychologists and paediatricians employ to study constructional difficulties in children tend to fall into two broad categories. In one group, the motor response required involves the use of a writing implement. The child is required to reproduce visual stimuli that vary in complexity from a single vertical or horizontal line to a complex many sided figure; these may be presented in different ways and the conditions for reproduction may also vary (e.g. copying versus drawing from memory). Among the best known of assessments in this category one might include the Developmental Test of Visual Perception (Frostig et al., 1961), the Bender-Gestalt Test (Bender, 1938), as well as the Developmental Test of Visual-Motor Integration (Beery, 1982) and the Goodenough-Harris Drawing Test (Harris, 1963). The latter two have been used in the present study. In the other group of tasks used to investigate constructional problems, the child must manipulate three dimensional objects in relation to a visual stimulus of some sort. In the present study, we have used the Griffiths form board as the prime measure of constructional ability. In addition, we used the Griffiths block design.

So far, we have shown that the prematurely born children in the cohort were less proficient than other children of the same age on the two relevant, norm referenced assessments employed in the study, i.e. the Griffiths form board and the Developmental

Test of Visual–Motor Integration. We have also shown that performance on these tasks was not influenced by gender, ethnic origin or SES. On both assessments, verbal IQ correlated significantly with performance but the amount of variance accounted for was very small (5% and 4% respectively).

In addition to demonstrating an overall difference between the premature children and their peers, we have also been able to provide convergent evidence from several analyses to suggest that constructional problems can occur as a specific deficit independent of failure in other aspects of performance. For example, in Chapter 6 we have shown that a small proportion of our cohort fell below the 15th percentile on either the Developmental Test of Visual–Motor Integration or Griffiths form board in isolation (n=3 and n=10, respectively) or on the two tests together (n=2). This suggests of course that even these two aspects of constructional ability may be dissociable. In Chapter 7, our analyses of the children's performance in relation to the type of brain lesion observed in the neonatal period provided weak but nevertheless positive support for the notion that different patterns of deficit may exist in relation to various lesions. For example, among the children with 'early' ventricular dilatation poor performance on the Developmental Test of Visual–Motor Integration was found, while children with a Grade IIa haemorrhage seemed to be poor on the Griffiths form board compared to their performance on other tasks. Finally, in Chapter 8 the use of cluster analysis has enabled us to identify a group of children whose performance on the Griffiths form board stood out as being exceptionally poor in comparison to their performance on other tasks. In the present Chapter we attempt to take the exploration of performance on this class of activity further, using the form board task as a prototype.

When watching children struggle with tasks such as form board completion or block design, one is struck by the gap between the measures that are traditionally taken and the potential richness of the data that might be obtained from more qualitative analyses. Time taken to complete the task and some measure of overall accuracy tend to be distilled into a single measure of performance that is age related, leaving the variation that exists in the way children approach the task to the imagination. In the present project, one of our objectives was to improve on the way these tasks are presented and analyzed in such a

way that we might obtain more information on the deficit(s) that underlie failure. We did this in two ways. First, we adopted the methodology employed by experimental psychologists in that we tried to manipulate certain parameters of the task systematically. Second, we attempted to supplement the quantitative data we obtained by undertaking a qualitative evaluation of specific aspects of the children's performance using videotape as the means of obtaining a permanent record of the actions involved.

In what follows, we present the work done on this aspect of perceptuo–motor performance in two parts. Since the timing of the project prevented us from undertaking extensive pilot work on this aspect of the work, we were forced to include a largely untried experimental manipulation, the success of which would become part of the project itself. Consequently our first objective is to evaluate the success of our new form board and its presentation to the children. Our second objective is to examine the characteristics of a small sample of children who find the task difficult and explore the extent to which their failure is associated with other measures we have taken. In particular, we will describe in qualitative terms the difficulties that these children seem to experience.

Part 1

The MASH form board

9.2 Introduction

The Griffiths form board was standardised in the 1960s and provides norms for children between the ages of 3 and 7 years. Although the task was satisfactory for our cohort as a crude measure of constructional ability the fact that very few children made errors when inserting the shapes, suggested that the test was reaching the limits of its sensitivity at this age. In order to produce a more sensitive measure, therefore, we began by designing a new form board called the MASH. The main difference between the two form boards is that the shapes included in the MASH form board were designed with the aim of increasing the visual attention needed to discriminate between them. Whereas the Griffiths form board consists of 11 shapes, the MASH consists of 12 shapes. Six shapes from the Griffiths form board were selected as the starting point for the MASH form board and for each of these a 'twin' shape was designed which differed only slightly from that of the original shape (see Figure 5.8).

When children have difficulty with form boards they make many different kinds of error. However, one of the most commonly noted is that they are insensitive to the orientation of the shape relative to the cavity beneath it. In some cases, such errors are soon corrected, in others the children continue to turn and twist the shape without success. From a completely different area of psychology we were attracted by the idea that we might study children's sensitivity to orientation in constructional tasks by producing an analogue of the study designed by Shepard and Metzler (1971). Although what they did required the subject to use only mental processes, as opposed to manipulating the objects, they were able to show that the time taken to recognize that two perspective drawings portrayed objects of the same shape, increased linearly with the orientation in which the shapes were depicted. In the present study we have adopted a similar procedure and changed the orientation of the shapes as they were displayed next to the board. This experimental manipulation led to a slightly different procedure in which the task was divided in three parts. Firstly, four shapes (the 2 stars and crosses) were presented in their

'normal' orientation (i.e. corresponding to that of the cavity). This was followed by the presentation of four other shapes (the 2 diamonds and symmetrical triangles) in a 'rotated' orientation, either 45, 90 or 120 degrees pivoted with respect to the cavity. Finally, the last four shapes (the 2 houses and asymmetrical triangles) were displayed in a mirror imaged (along the vertical axe) or 'turned' orientation relative to the cavity (see Figure 5.10).

In this first part, our objective was to establish that the two form boards actually differ in level of difficulty and to see how successful the experimental manipulation was. The specific aims were to examine whether, (1) the MASH form board is a more challenging task for children in general to complete than the Griffiths form board, (2) which other variables were associated with performance on the MASH form board, and (3) an experimental manipulation of the orientation of groups of shapes affected performance.

Subjects

For this part of the Chapter, the data of the premature children who were assessed on both the Griffiths and MASH form board and who were not classified as having a central motor deficit (n=151), and the 64 reference children (see Chapter 5) were combined to form a total sample of 215 children.

Measures

Detailed descriptions of the shapes and procedures involved in the Griffiths and MASH form board (including the pilot studies) can be found in Chapter 5. In addition, performance on the manual dexterity items of the Movement ABC Test, visually matching the shapes of the MASH form board, and a measure of school attainment, Word Reading (BAS), are included in the first part of this Chapter [1].

Data analyses

Parametric tests applied to the data consisted of MANOVAs or multiple regression

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[1] *The Word Reading Scale scores are used here because this was the only Scale the reference children were assessed on.*

analyses. Post-hoc analyses consisted of the Tukey method. Since this was an exploratory study, a significance level of .05 was established.

9.3 Results

Speed and accuracy on both form boards

Speed

Before the data entered the analysis, a new total time to complete the MASH form board was calculated to compensate for the fact that this form board has one shape more (i.e. 12 shapes) than the Griffiths form board (i.e. 11 shapes). Without this adjustment the difference in total time to complete the two form boards would have been artificially increased. Therefore, each child's total time to complete the MASH form board was divided by 12 and then multiplied by 11. For example, a child who took 60 seconds, was given a time of 55 seconds as the new adjusted time on the MASH form board.

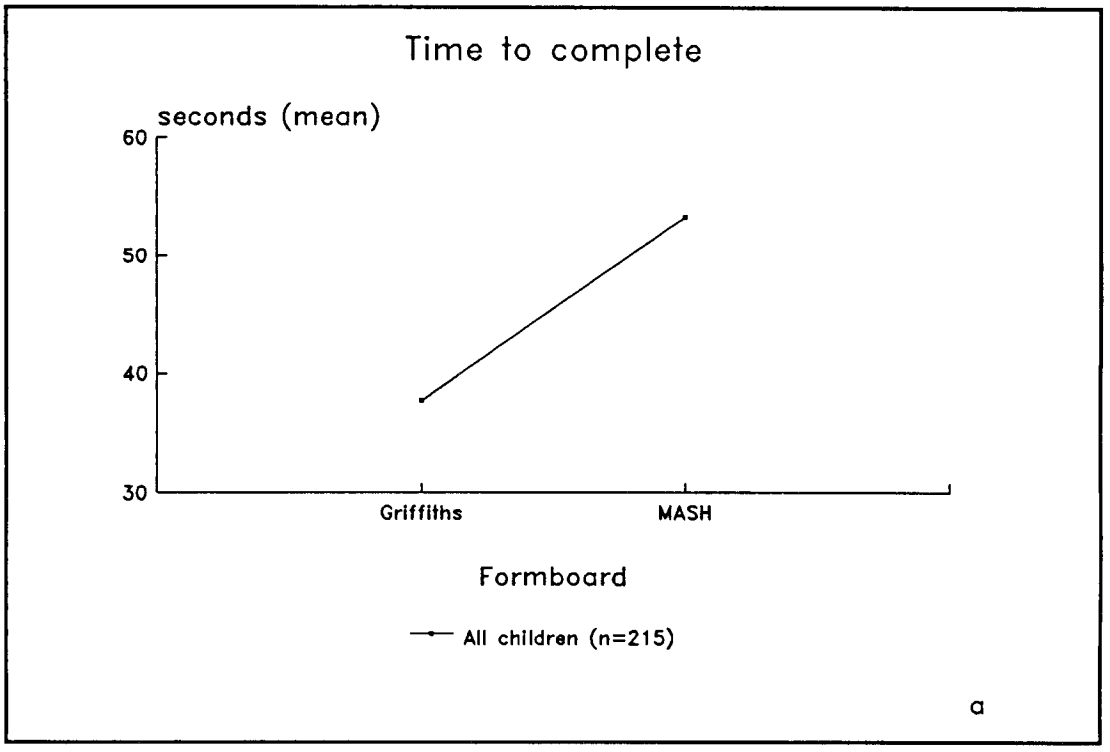
As can be seen from Figure 9.1a, it took the combined group of children an average of 37.72 seconds (SD=13.79) to insert the shape of the Griffiths, while the (adjusted) average time to complete the MASH form board was 53.32 seconds (SD=25.22). This difference reached statistical significance ($F=87.68$, $df=1,214$; $p<.0001$).

Accuracy

Again, the same adjustment for total number of errors on the MASH form board was calculated to account for the increased possibility of making more errors on this form board by the mere fact that it consisted of 12 shapes. Figure 9.1b shows the mean number of errors made on each of the form boards. In addition to taking longer to insert the shapes, the children also made significantly more errors on the MASH form board (mean number of errors was 0.44, SD=0.74 on the Griffiths and 2.51, SD=1.69 on the MASH form board).

Relation speed and accuracy

The relationship between time and errors is graphically depicted in Figure 9.2. The correlation coefficients for the Griffiths and MASH form board were similar, $r=0.51$ and $r=0.56$ (both $p<.0001$), respectively.



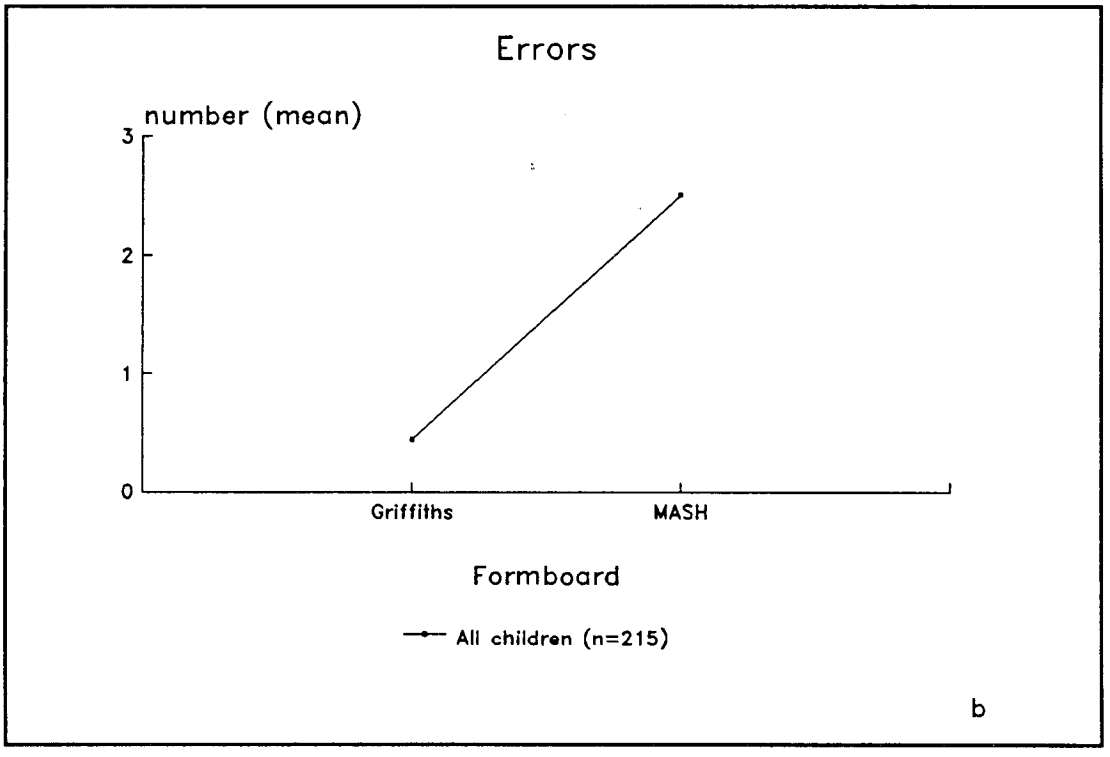
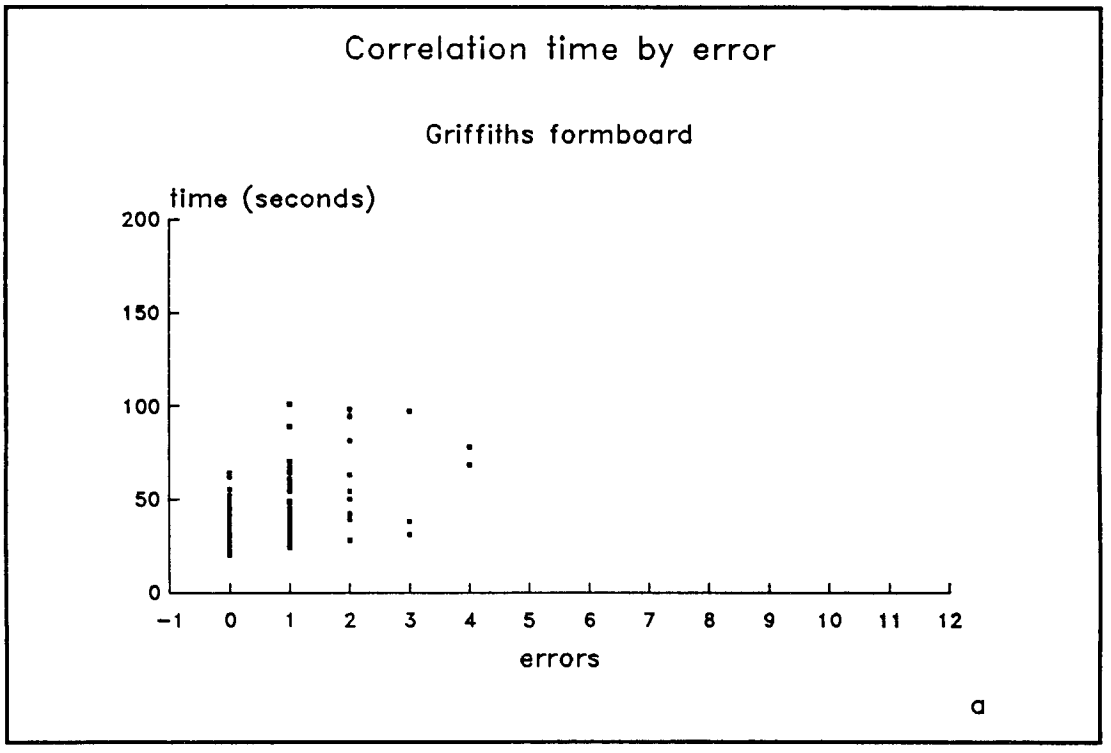


Figure 9.1: Mean time taken to complete (a) and number of errors (b) while inserting the shapes of the Griffiths and MASH form board (adjusted) for all children (n=215).



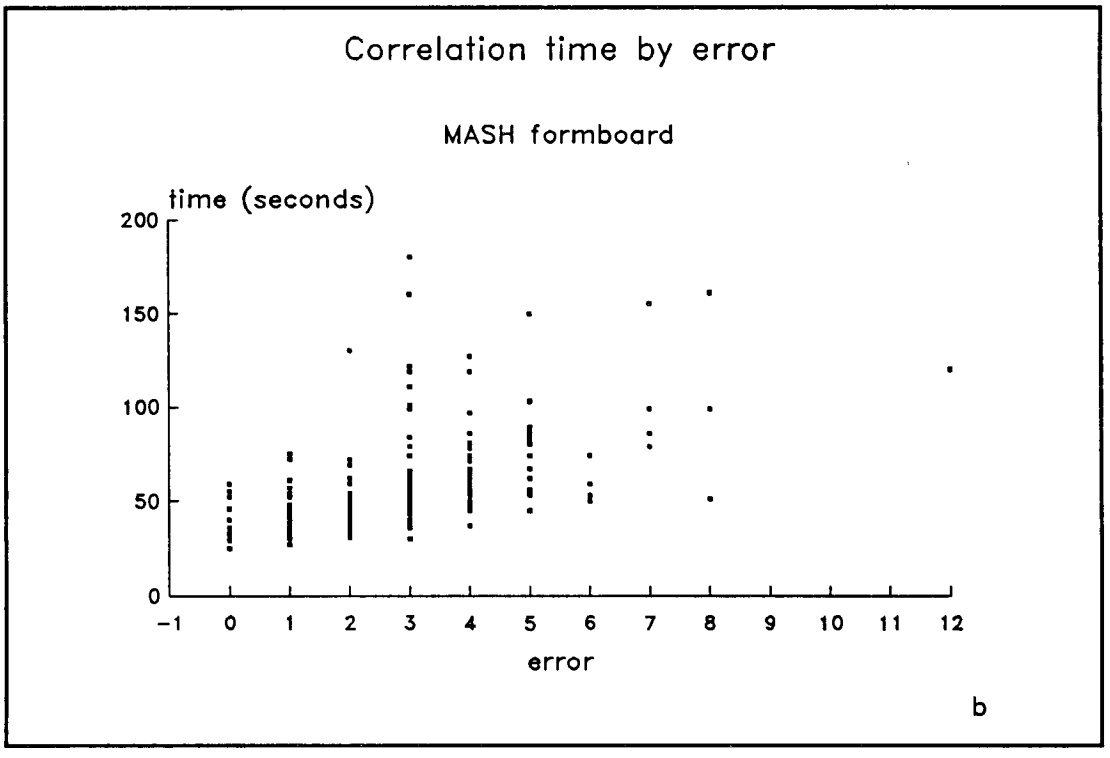


Figure 9.2: Relation between speed and accuracy on the Griffiths (a) and MASH (b) form board for all children (n=215).

Type of error on the MASH form board

On average, the 215 children made 3.14 errors (SD=1.68) while visually matching the shapes of the MASH form board and 2.74 errors (SD=1.84) while inserting the shapes ($F=24.20$, $df=1,214$; $p<.01$). Table 9.1 shows the distribution of errors per shape.

Table 9.1: Distribution of errors on the MASH form board (n=215).

Shape	**Visual matching** number (%) of errors	**Insertion** number (%) of errors
Star 1	42 (6.1 %)	13 (2.2 %)
Star 2	16 (2.3 %)	17 (2.9 %)
Cross 1	72 (10.4 %)	36 (6.1 %)
Cross 2	44 (6.4 %)	39 (6.6 %)
House 1	83 (12.0 %)	52 (8.8 %)
House 2	75 (10.9 %)	55 (9.4 %)
Diamond 1	21 (3.0 %)	47 (8.0 %)
Diamond 2	45 (6.5 %)	35 (5.9 %)
Sym. triangle 1	24 (3.5 %)	30 (5.1 %)
Sym. triangle 2	96 (13.9 %)	122 (20.7 %)
Asym. triangle 1	79 (11.4 %)	75 (12.8 %)
Asym. triangle 2	94 (13.6 %)	68 (11.5 %)
Total	691 (100 %) mean=3.14 (1.68)	589 (100 %) mean=2.74 (1.84)

Although the children made significantly more errors in the visual matching task, from Table 9.1 it is clear that some shapes resulted in less errors than others in *either* the visual matching *or* the insertion task. While Star 2 appeared the most easy, symmetrical triangle 2 appeared the most difficult. The 'twin' shapes which we created seemed more easy for the children to deal with when they were not triangular. Overall, apart from a few exceptions (i.e. star 1 and cross 1), the order of difficulty among the shapes was similar in the two tasks ($r_s=0.81$, $p<.001$).

Variables associated with performance on the MASH form board

To examine the variables associated with (successful) completion of the MASH form board two multiple regression analyses were run. Five variables were chosen to enter the analyses. To examine the contribution of manual dexterity to performance scores on the 'bicycle trail', 'posting coins' and 'threading beads' items of the Movement ABC Test were chosen. To evaluate the degree of association between visual discrimination ability and performance, total errors made while visual matching the shapes of the MASH form board entered the analyses. The last variable came from the cognitive ability assessment (BAS) and comprised scores on the Word Reading Scale representing a measure of academic attainment. Results of evaluation of assumptions underlying multiple regression led to a log transformation of the speed measure on the MASH form board to reduce the skewness of the distribution.

Stepwise regression was employed to determine the hierarchy among the independent variables in their prediction of time to insert the 12 shapes of the MASH. Table 9.2 displays the unstandardized regression coefficients (B), the standardized regression coefficients (*b*=beta), the semipartial correlations (sr^2), and R, R^2, and the adjusted R^2 for all children.

As can be seen from this Table, only two of the independent variables contributed significantly to prediction of time to complete the MASH form board. These variables are thought to represent bi–manual coordination and visual discrimination ability. Altogether, 16% (15% adjusted) of the variance in speed of performance on the MASH form board was predicted by knowing scores on the 'threading beads' and visual matching the shapes of the MASH form board variables. In contrast, visually matching the shapes of the MASH form board was the only significant predictor of accuracy of performance on the MASH form board (adjusted R^2=.04) However, as can be seen from the R^2 value, only little variance could be predicted by knowing the visual discrimination scores.

Table 9.2: Stepwise regression of manual dexterity, visual discrimination and cognitive ability variables significantly contributing to speed and accuracy of performance on the MASH form board (n=215).

Variables	B	*b* (beta)	sr^2 (incremental)	
Speed				
1. Threading beads	.005	.27	.10 ***	R^2=.16
2. Visual matching shapes of MASH	.025	.25	.06 ***	aR^2=.15 R=.40 ***
Accuracy				
1. Visual matching shapes of MASH	.234	.21	.05 ***	R^2=.05 aR^2=.04 R=.21 ***

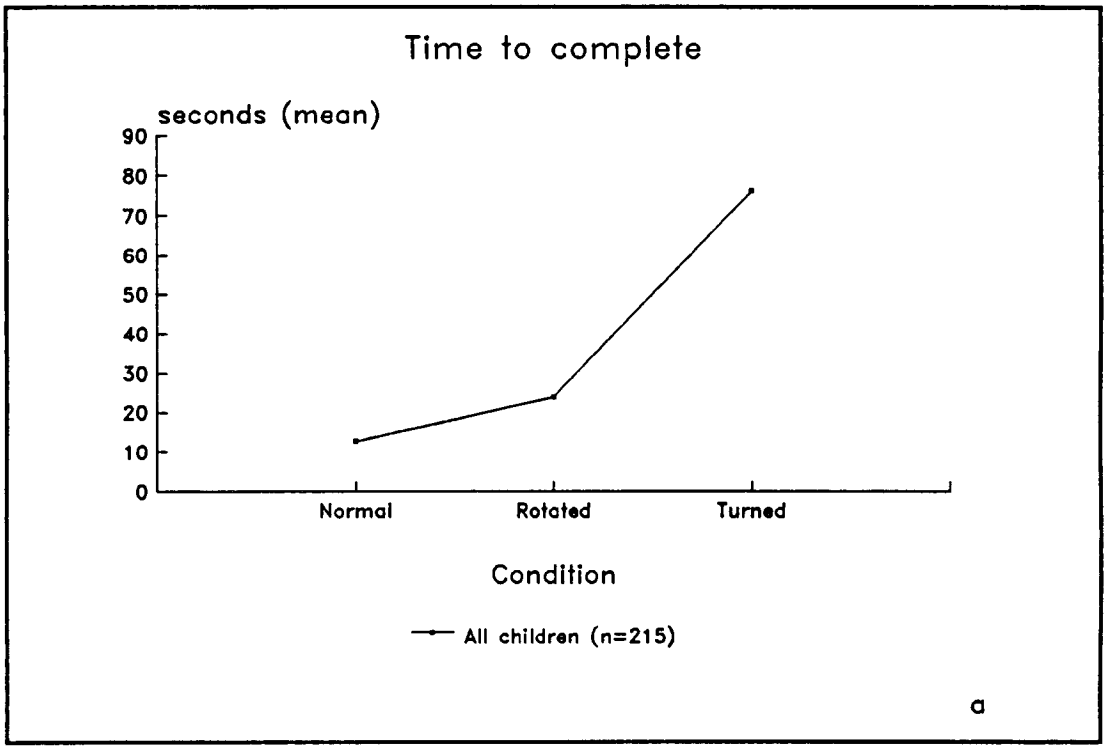
*** p<.001

Does orientation of shape affect speed and accuracy of insertion?

So far, we have looked at speed and accuracy of inserting shapes in a straightforward way, i.e. the child was presented with all shapes of the Griffiths and MASH form board in an orientation corresponding to that of the cavity in the board. The task for the child was to lift the shape, find the corresponding cavity, transport the shape to the cavity and insert it [2] . We now turn to the results of the experimental manipulation in which the orientation of the shapes of the MASH form board as they were presented to the child was varied.

The analysis on time to insert the shapes in each of the three conditions revealed a main effect of condition (F=327.65, df=2,428; p<.0001). As depicted in Figure 9.3a, the mean time to insert the shapes in the 'normal' orientation was 12.65 seconds (SD=6.85), in the 'rotated' condition 24.04 seconds (SD=18.61), and in the 'turned' condition 76.24 seconds

[2] *Or, alternatively, locate a cavity in the board, look for the corresponding shape, lift, transport, and insert the shape. We will elaborate on strategy used a little later in this Chapter for a small sub-sample of children.*



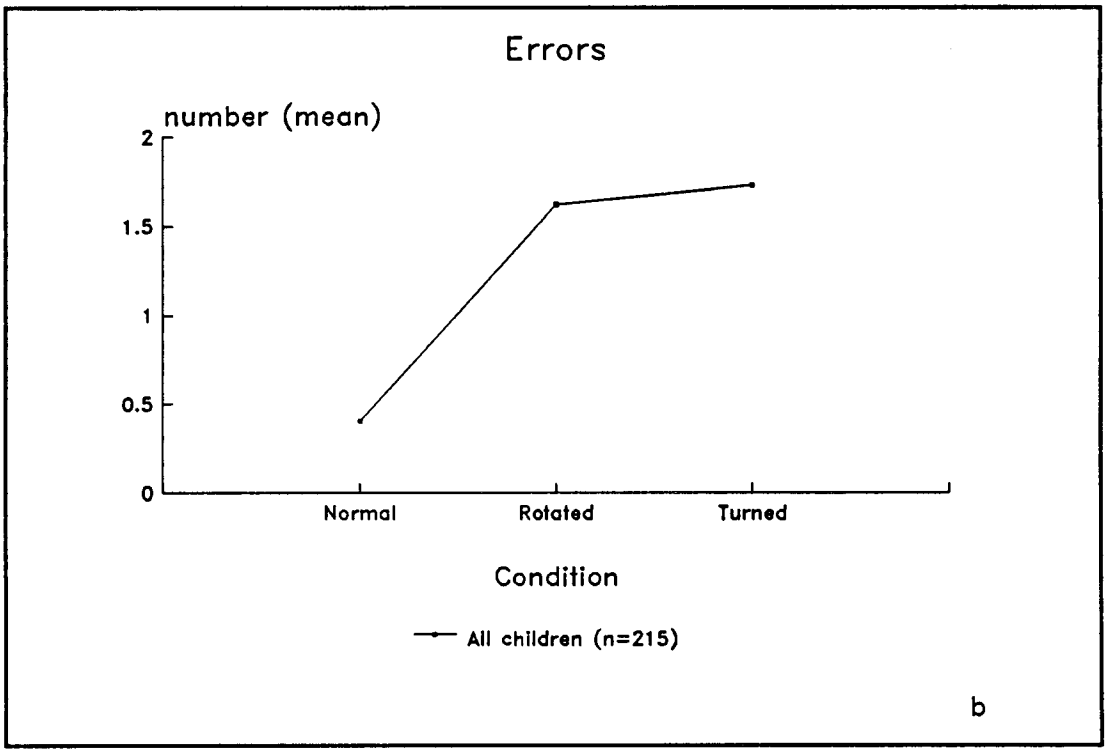


Figure 9.3: Mean time taken to complete (a) and number of errors (b) while inserting the shapes of the MASH form board in three conditions for all children (n=215).

(SD=46.29). Post-hoc analysis showed that the time taken to insert the shapes increased significantly across the three conditions (all $p<.01$).

The outcome of the analysis on accuracy of performance was initially comparable to that on speed of performance and revealed a significant main effect of condition ($F=116.28$, $df=2,428$; $p<.0001$). As can be seen from Figure 9.3b, the pattern of performance across the conditions showed that a deviation from the 'normal' orientation caused the children to make significantly more errors (all $p<.01$). However, in contrast to speed of performance there was no significant difference between number of errors in the 'rotated' and 'turned' conditions.

9.4 Discussion

There has been a long tradition in developmental assessment of including tasks in which children must handle objects and materials in various ways to build or construct something. For the young child tasks such as picture puzzles, paper folding and building a bridge of blocks were included in, for example, the Merrill-Palmer Scale of Mental Tests (Stutsman, 1931), the Minnesota Preschool Scale (Goodenough et al., 1940), the Bayley Scales of Infant Development (Bayley, 1969), and the Denver Developmental Screening Test (Frankenburg et al., 1973). These tasks are still popular and are also included in more recent developed assessments such as the Miller Assessment for Preschoolers (Miller, 1988). As the child gets older more complex block designs such as those in the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 1967) and the McCarthy Scales of Children's Abilities (McCarthy, 1972), and form boards (Griffiths, 1967) are introduced. Sometimes, the child is asked to complete the constructional task in his/her own time, i.e. self-paced. At other times, the child is put under time-pressure and required to complete the tasks as fast as possible. Adding the element of time-pressure to the instructions may be one way of creating a situation which reveals subtle difficulties that are otherwise compensated for.

Despite the attention given to assessing visual-spatial and visuo-motor skills in a child's early development and the huge popularity of toys and games involving a variety of shapes (e.g. the posting box), few researchers have studied the processes involved in

constructional tasks in more detail. In this part of our study we introduced a novel measure of constructional ability, the MASH form board which was based on the form board designed by Griffiths (1967) but included other, similar looking shapes with the aim of increasing the overall level of difficulty of the task. The results showed that the 215 6–year–olds tested had more difficulty with the MASH than the Griffiths form board. There was a significant increase in both the time taken and number of errors made while inserting the shapes of the MASH form board. The new form board, however, did not appear to be too difficult for children of this age because there was considerable overlap in time to complete and number of errors with the Griffiths form board (see Figure 9.2).

In the present study, children made more errors in the visual matching task than in the insertion task. There are two possible reasons for this observation. First, when visually matching, the correct cavity out of 12 possible cavities has to be found each time. In contrast, when inserting the shapes the number of alternative cavities decreases with an increasing number of shapes correctly inserted. Secondly, this could be due to a practice effect: the visual matching task was administered before the insertion task which means that the child was already familiar with the shapes when they were asked to insert them into the board.

Inspection of the relation between type of shape and frequency of error suggested that our 6–year–old children had most difficulty with correctly dealing with triangular shapes in either the visual matching or insertion task. From studies focusing on the ability to copy or draw shapes from memory it is known that below the age of 7 or 8, children find it more difficult to reproduce a diamond than a square (Chen & Freeman, 1984). Similarly, children experience greater difficulty with oblique lines compared to horizontal or vertical lines in visual discrimination tasks (Somerville & Bryant, 1985). From the results of the present study, we can add that 6–year–old children also have more difficulty with the action of inserting shapes consisting of oblique sides in a form board.

It was interesting to note that performance on the visual matching task of the MASH shapes was a predictor of inserting the shapes in the MASH form board. However, despite reaching statistical significance little variance in the speed or accuracy of performance

could be explained by knowing how well the child could match the shapes. In other words, it does not seem that there is a strong relationship between being able to recognise that a shape will fit into a certain cavity and the actual action of inserting the shape. This implies that although a child undoubtedly utilises visual cues to compare shape and cavity, superior or inferior ability on this component of the task does not necessarily lead to fast and accurate performance. The results of a study by Hirsch and Niedermeyer (1973), focusing on handwriting performance, seem to support this dissociation between recognition and (letter) construction. They provided groups of children with different types of handwriting practice, i.e. copying only, copying plus letter discrimination, faded tracing only, and faded tracing plus letter discrimination. Pre- and post-training evaluations consisted of a letter formation test and a test of visual letter discrimination. Although performance of the children who received visual discrimination practice improved considerably on the post-training letter discrimination test, they failed to outperform the other children who had not received this particular type of practice on the letter formation post-training test. The authors concluded, therefore, that "..letter discrimination ability does not seem to transfer to letter formation performance." (p. 86). These same findings, i.e. that adequate visual analysis is a necessary but not sufficient prerequisite for construction, have also been reported following training of children in copying or visually discriminating geometric shapes (Wright Rand, 1973).

Experimental manipulation of the orientation of shapes

Following a procedure similar to that of Shepard and Metzler (1971) we investigated how 6-year-old children solve the problem of inserting a shape into a form board when the orientation of the shape is incongruous with the orientation of the corresponding cavity. In addition to a 'baseline' condition where there was no conflicting information between shape and cavity (the 'normal' condition), two other conditions were created which each increased in (assumed) level of difficulty. The 'rotated' condition was designed as an intermediate level in which only a slight rotation through the picture plane was necessary to resolve the problem. The 'turned' condition was thought to be the most difficult for the children to solve and required rotation of the shape through the three-dimensional plane in order to insert it into the cavity. The results of this experimental manipulation showed that the time required to insert the shapes increased significantly across the three

orientation conditions. In addition, the number of errors increased significantly when the orientation of the shape deviated from the orientation of the cavity. Therefore, our hypothesis that the way a shape is presented, i.e. in different orientations, has an effect on insertion was confirmed.

If it were assumed that the time taken to physically insert a shape into a cavity (the 'motor' component of the task) is similar for each of the 12 shapes of the MASH form board, then it may be hypothesised that the increase in time observed in the 'rotated' and 'turned' condition represents an increase in time needed to perceive how the shape should be inserted. In other words, the child first has to imagine the shape as rotated into the same orientation as the cavity before proceeding to insert it, and that this 'mental rotation' (to use the terminology of Shepard & Metzler, 1971), accounts for the observed increase in time. Although all children eventually succeeded in inserting the shapes in the 'turned' condition, it seems that 6-year-old children have not yet completely grasped that a fundamental invariant of the world is that objects can rigidly transform in relation to themselves in three-dimensional space (Shepard & Farrell, 1985). Future studies should be directed at investigating this phenomenon among children of various ages.

Improvements in design of the study

As this study proceeded we realised that certain aspects of the design of both the materials and procedures could be improved. Three of these are briefly outlined below and we strongly recommend that they are considered in future studies:

1) *More varied visual discrimination task*

In the present study it was not possible to establish whether the steep increase in time taken to insert the shapes in the 'turned' condition was mirrored by a similar increase in time (or number of errors) when the child was only required to visually match the shape with its cavity. Therefore, the shapes should also be presented in a 'rotated' and 'turned' orientation during the visual matching task (i.e. along the lines of the procedure used by Shepard and Metzler, 1971) instead of only in their 'normal' orientation.

2) *Consistency of procedure across tasks*

Some children in this study clearly benefitted from the fact that the number of options left to them diminished as more and more shapes were successfully inserted. Therefore, a different procedure should be adopted in which each shape is removed from the board once it has been inserted. This procedure would require the child to consider the 12 cavities in every trial and is more consistent with the procedure adopted in the visual matching task.

3) *Altering the shapes included in the MASH form board*

The 12 shapes of the MASH form board were subdivided in 3 groups which each consisted of 2 'twin' pairs. Each group of shapes was then successively presented in one of three orientations. However, from the number of errors per shape in the visual matching and insertion tasks it emerged that there was a hierarchy among the shapes (see Table 9.1). In other words, including those shapes in the 'turned' orientation with which the children had already most difficulty with in a 'normal' orientation may have exacerbated the time taken and number of errors. Although it would not make sense to present the stars in a different orientation, the remaining shapes could all be presented in a different orientation (except for the crosses in the 'turned' condition) to avoid bias of intrinsic difficulty of shape. Alternatively, we suggest that the stars and crosses are replaced by other shapes which would allow for a better discrimination in the orientation conditions.

Part 2

Children with poor constructional ability: Quantitative and qualitative aspects of performance

9.5 Introduction

As was shown in Chapter 8, the premature children identified as having perceptuo-motor problems could be sub-divided into six groups, each of which showed a different profile of performance across a range of tasks. One of these groups, Cluster 6, is of particular interest in relation to constructional ability. The profile of this group was characterised by a discrepancy between poor performance on the Griffiths form board and good performance on tasks measuring accuracy and speed of hand movement, ball skills and static/dynamic balance. These findings seem to provide some support for the idea that an impairment in constructional ability may exist independent of performance in other areas of perceptuo-motor functioning.

As discussed previously, some researchers have used the label 'clumsiness' to refer to all children with perceptuo-motor problems (e.g. Henderson & Hall, 1982), while others have used the term 'developmental dyspraxia' (e.g. Denckla, 1984; Cermak, 1985). However, following observations in adults with acquired apraxia, it has been suggested that the term 'dyspraxia' should be reserved for only those children who have difficulty in the planning and sequencing of movements but who demonstrate normal perceptuo-motor ability and whose basic motor skills are intact (Deuel, 1992). Also, it was noted that it seems to be possible to distinguish between children who have difficulty in imitating or spontaneously generating representational or non-representational gestures (gestural dyspraxia) (Denckla & Roeltgen, 1992; Cermak, 1985), and children who have difficulty with "..planned movements for any kind of task involving the structuring or arranging of objects, parts of objects, or lines in two and three dimensional space." (constructional dyspraxia) (Miller, 1986; p.56). As the present study did not include an assessment of gestures, we were unable to determine whether children with gestural dyspraxia existed among our cohort. However, some of our assessments fall within the realm of those generally used to evaluate the presence of an impairment in constructional ability. For example, Miller

(1986) suggested that problems in completing form boards may be one possible expression of constructional dyspraxia. Others mention failure on two- or three-dimensional block designs (Cermak, 1985) or difficulties with copying geometrical designs or letters and/or spontaneous drawing (Deuel, 1992) [3] . De Ajuriaguerra and Stambak (1969) suggested that some dyspraxic children have faulty visualization of spatial and temporal organisation of movement action. Although constructional dyspraxia is still a controversial and ill-defined category of motor skill disorders, the dissociation of abilities revealed by children in Cluster group 6 led us to examine this phenomenon in more detail.

What is clearly lacking so far in studies of children who have difficulty in performing and/or acquiring perceptuo-motor skills is an attempt to supplement quantitative measures of impaired performance with qualitative descriptions of the observed behaviour. Admittedly, how we move is difficult to describe concisely when simply watching a child, but nowadays even simple techniques such as detailed analysis of video recordings enable us to capture more detail than was possible before. Although more researchers now venture down this pathway, the data base on children with perceptuo-motor difficulties remains impoverished. Exceptions are studies by, for example, Kalverboer and Brouwer (1983) and Barnett (1992).

The objective of this part of the thesis is twofold. Our first concern is with the concept of constructional dyspraxia and the extent to which our data provide support for the idea that such a 'syndrome' exists as a separate entity among children with perceptuo-motor difficulties. Our second, and main concern is with characterising the difficulties some children have with form board tasks.

In order to examine these two questions in conjunction, we have elected to use slowness of performance on the form board task as our primary criterion for constructional difficulties. We, therefore, began our analyses with the earlier mentioned group of children who were identified in the previous Chapter as showing an uneven profile in perceptuo-motor abilities with slowness at completing the Griffiths form board task as the most

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[3] *Referred to by Denckla & Roeltgen (1992) as 'constructional dysgraphia'.*

striking feature. A subset of these children was identified who were equally slow in completing the MASH form board to ensure that the classification of children according to the speed of their performance was reliable across more than one version of the task. To obtain a full picture of their characteristics these children were then matched to a control group of premature children who completed the form boards quickly.

Subjects

The 13 children who made up Cluster 6 had all obtained times on the Griffiths form board which fell below the 15th centile compared to that of the reference children. In addition, 3 more children showed a similar profile but were excluded from the cluster analyses purely on statistical grounds (recall that outliers have to be excluded to avoid distortion of cluster formation). Twelve out of these 16 children proved to be equally slow on the MASH form board (<15th centile) and were, therefore, consistently slow in their time to complete the two form boards [4].

To select a control group we started by identifying all premature children whose overall speed in completing the two form boards was consistently fast, i.e. times above the 50th centile as compared to the reference children. Since an association between constructional skills and verbal ability had been noted previously in Chapter 6, we then proceeded to select 12 children out of this pool of fast children and matched them individually to the slow children on the basis of similarity in T-scores on the BAS Subscales measuring verbal ability [5] . The range of T-scores among the slow children was 42 to 66 (mean=51; SD=8), while this was 43 to 65 among the fast children (mean=51; SD=7) [6].

Measures

In addition to the measures included in part 1 of this Chapter, we now report the

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[4] *In contrast to their performance on the Griffiths form board, the times obtained by the remaining 4 children on the MASH form board ranged from 44 to 55 seconds, which placed them above the 25th but below the 50th centile.*

[5] *The Similarities and Naming Vocabulary Scales of the BAS.*

[6] *The slow children also made significantly more errors than the fast children on the Griffiths ($t=2.73$; $p<.05$) and MASH form board ($t=5.26$; $p<.0001$).*

following: performance on the block design of the Griffiths Mental Development Scales, the Developmental Test of Visual-Motor Integration, the Goodenough-Harris Draw-a-man Test, Matching Letter-Like Forms (BAS) and the visual acuity assessment. In addition, scores on the Movement ABC Test and Touwen's neurological Examination are included.

Qualitative observations of performance on the MASH form board were obtained from video recordings which were available for all but one (slow) child [7]. These were randomly presented to two experimental psychologists (SH who was one of the co-directors of the study and LH) who together with the author (MJ) wrote down short descriptions of each child's performance. These descriptions were then compared and, if necessary, the recording was viewed again to clarify particular observations. The descriptions of the three observers were combined to form one overall profile of quality of performance. All observers had previous experience of rating movement skills. Descriptions of the categories used to evaluate quality of performance are discussed in paragraph 9.6.3.

Data analyses

For the quantitative data, the nonparametric X^2 test and parametric tests such as the one-way mixed measures ANOVAs or matched pairs t-tests were applied with the alpha-level set at .05.

9.6 Results

This section starts with the presentation of data relevant to the question of whether constructional dyspraxia exists. We then proceed to examine in detail the performance of the children with difficulties on the form board tasks.

9.6.1 Constructional dyspraxia - does it exist?

This question was examined in two ways. First, the slow group was compared to the fast group on all of the assessments that we believed to be part of the characteristics of

[7] *This child was assessed in her own home.*

constructional dyspraxia. We then compared the groups on other assessments that fall within the category of general perceptuo-motor assessments but cover rather different aspects of performance. Finally, three neonatal variables were included in the analyses to see whether any obvious relationship between these and group membership existed. Following these analyses, the profiles of the children within the slow group were examined to obtain a picture of their performance across the constructional tasks used in the study.

Results

a) Group comparisons

Table 9.3 summarizes the outcome of the groups of children who were consistently slow or fast in completing the form boards on the other constructional tasks, the global assessments of perceptuo-motor competence and neurological status, the vision and visual discrimination tasks, and their neonatal characteristics.

The groups did not differ in their ability to successfully reproduce the three block designs (design I: X^2=1.04, df=1, p>.05; design II X^2=3.00, df=1, p>.05; design V: X^2=1.70, df=1, p>.05). However, the results of the analysis on the time taken to complete the designs showed a main effect of group (F=5.53, df=2,22; p<.05) and design (F=16.53, df=2,44; p<.0001). There was no interaction between group and design (F=0.00, df=2,44; p>.05). Thus, the children who were consistently slow in inserting the shapes of the form boards were also slow in putting the blocks together, irrespective of the complexity of the design. Both groups of children found design III the most difficult one to reproduce quickly. This design differed from the other two designs in that it contained a diagonal row of blocks of the same colour (see Figure 5.13).

In Chapter 8 it was noted that scores on the Developmental Test of Visual-Motor Integration related closely to performance on the Griffiths form board among children with perceptuo-motor problems (Factor 4). Indeed, when the slow children were compared to their matched premature peers a significant difference (t=3.21, p<.01) was found on the standard scores.

Table 9.3: Outcome of the slow and fast groups on the constructional tasks, the global assessments, vision and visual discrimination and neonatal characteristics (mean; SD or median; range).

	Slow	Fast	p
Other constructional tasks			
Block Design (*seconds*) II	24.8 (10.1)	16.6 (3.6)	group *
III	43.7 (13.0)	35.9 (20.5)	design ***
IV	29.2 (16.8)	20.9 (4.1)	interaction ns
Visual-Motor Integration (*standard score*)	7.2 (1.6)	9.6 (2.2)	**
Draw-a-Man (*score*) motor	0.15 (0.19)	0.30 (0.26)	group *
proportion	0.41 (0.25)	0.63 (0.25)	component ***
depiction	0.55 (0.17)	0.70 (0.18)	interaction ns
detail	0.15 (0.18)	0.18 (0.15)	
Global assessments			
Movement ABC Test (*total score*)	4.6 (4.0)	3.9 (3.8)	ns
Movement ABC Checklist (*total mean score*)	0.66 (0.29)	0.82 (0.61)	ns
Touwen's Examination (*total score*)	39.4 (4.4)	39.8 (5.8)	ns
Vision and visual discrimination			
Near acuity (*score; N*)	4.5 (4.5-6)	4.5 (4.5-5)	ns
Matching MASH (*errors*)	3.4 (1.4)	2.7 (1.3)	ns
(*seconds*)	108.4 (9.3)	104.4 (17.5)	ns
Matching Letter-Like Forms (*T-score*)	47.1 (10.4)	56.3 (5.1)	**
Neonatal characteristics			
Gestational age (*weeks*)	30 (2)	31 (2)	*
Birthweight (*grams*)	1154 (315)	1410 (427)	ns
Brain lesion observed	7	3	ns

* p<.05; ** p<.01; *** p<.001; ns=not significant

In addition to the shape copying task each child was asked to draw a picture of a man (Goodenough–Harris Drawing Test; Harris, 1963). Following the example by Barnett and Henderson (1992), the composite scores were subdivided into four components, each representing a different aspect of performance: 1) motor control and coordination 2) representation of proportions 3) the depiction of particular features and 4) the awareness of detail in any feature. The results of the analysis showed a main effect of group ($F=5.21$, $df=1,20$; $p<.05$) and component ($F=43.28$, $df=3,60$; $p<.0001$). The interaction between group and component did not reach statistical significance ($F=1.487$, $df=3,60$; $p>.05$). Thus, there was no specific component of drawing which stood out as being less well executed by the slow children, but the quality of their drawing was generally poorer than that of their matched peers.

On the broad based assessments of perceptuo–motor performance, i.e. the Movement ABC and Touwen's neurological Examination, there were no differences between the groups. Also, there was no indication that the slow children were considered to be less able than the fast children by their teachers. Since the bi–manual coordination task, threading beads, was a predictor of speed of performance on the MASH form board (although accounting only for a small proportion of the variance) the raw scores on this and the two other manual dexterity items included in the Movement ABC Test were compared for each group. None of these items differentiated between the groups.

With regard to vision we could not find a difference between the groups. The near visual acuity scores of slow and fast children were similar ($X^2=0.49$, $df=1$; $p>.05$) with all but 3 children obtaining a score of N 4.5 [8] which is appropriate for children of this age. However, there was some indication that the slow children were poorer at perceiving the difference between visual stimuli on one of the two visual discrimination tasks. On the first task, i.e. visually matching the shapes of the MASH form board, the slow children did not make significantly more errors than the fast children ($t=1.43$; $p>.05$). Furthermore, the type of error made was similar among the groups. When making an error, most

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[8] *N 4.5 implies that the child saw all the test letters on the N 4.5 line at a distance of 25 cm or more.*

children pointed to the obvious alternative, i.e. the other shape belonging to a pair. The shapes which caused most confusion were the two asymmetrical triangles. Among the slow children, 22% of the total number of errors involved these shapes, while this was 34% among the fast children. Since the main characteristic separating the two groups was their slowness in inserting shapes, the time taken by each child to match the MASH shapes was examined. Although none of the inept children were as quick as the fastest children in the competent group, overall times were similar ($t=0.86$, $p>.05$). However, on the second visual discrimination task, i.e. the Matching Letter-Like Forms Scale of the BAS, the slow children made significantly more errors than the fast children ($t=3.95$; $p<.01$). In other words, they were poorer at discriminating between the orientation of shapes.

Finally, examination of the 3 neonatal variables showed that, as a group, the slow children were born slightly earlier than the fast children ($t=2.39$; $p<.05$), but their mean birthweight did not differ significantly from that of the fast children ($t=1.50$; $p>.05$). Although 7 of the slow children had shown an abnormal ultrasound scan in the neonatal period and only 3 fast children had done so, this difference was not significant ($X^2=2.74$, $df=1$; $p>.05$).

b) Individual profiles of slow children

Although the between group differences just described are of interest, such analyses inevitably mark the variability in performance among the slow children. Therefore, the individual data for these children were examined in more detail. Tables B.1 and B.2 in Appendix B provide the raw data for the slow children on the form boards, block design, two graphic tasks, and other variables. The children are listed in ascending order of verbal ability scores. An overview of these data together with any other observations are provided in Table 9.4.

The scores of these children were inspected in a somewhat different way as reported before. First, except for the block design and Draw-a-man tasks, we made a distinction between scores which fell below the 50th, 25th or 15th centile. On the block design only one cut-off point (<15th centile) was provided by Griffiths (1967). In addition, we looked whether the time taken by the slow children corresponded to that of the cut-off points for

5- or 7-year-olds. For the Draw-a-man task it was decided that a score below 0.10 on any of the four components was very poor, scores between 0.10 and 0.25 as poor and scores above 0.50 as acceptable.

Table 9.4: Summary of individual data for the 12 slow children.

Ss	BD	GS		MD	VA	VD		Neonatal charact.	Other observations
		VMI	DAM			MASH	MLF		
1	#	$	*	#		*		No lesion	poor ball skills
2	#	#	#	#		#	*	I + flares <1000 gr	-
3	#	#	#		#			vent. dil.	-
4	*		#			*		Infarct	poor ball skills no stereoscopic vision
5	#	*		#		*		flares < 7 <1000 gr	poor ball skills
6		#	#				#	I <1000 gr	low neurological optimality score
7			#				#	No lesion	low neurological optimality score
8	$	*						No lesion	-
9	#	*	#				#	I + flares <1000 gr	no stereoscopic vision
10			#			*		No lesion	-
11	*	*	not tested	#		#	#	No lesion <1000 gr	low neurological optimality score
12	$	#	#				#	flares < 7 <1000 gr	poor balance

Legend: #=*below* 15th centile; *=*below* 25th centile or when no cut-off point available judged as poor; $=*above* 50th centile or judged as good; BD=Block Design; GS=Graphic skills; VMI=Developmental Test of Visual-Motor Integration; DAM=Draw-a-Man; MD=Manual dexterity (Movement ABC Test); VA=Near visual acuity; VD=Visual discrimination; MASH=Visually matching shapes of MASH form board; MLF=Matching Letter-Like Forms Scale.

Discussion

The slow children presented in this part of the thesis shared two characteristics. First, they were all identified by the cluster analyses as showing similar profiles of performance across a wide range of perceptuo-motor tasks. Secondly, each of these 12 children were consistently slow in their performance on the Griffiths and MASH form board tasks. We examined the scores of these children in more detail to investigate whether they shared any other characteristics which would allow us to determine whether or not the phenomenon of 'constructional dyspraxia' existed among this cohort of prematurely born children.

Three aspects of our results leave us to conclude that it does seem possible to identify children who have specific difficulty with constructional tasks. First, group comparisons showed that the children who were consistently slow and inaccurate on the form boards could be distinguished from children who were consistently fast and accurate on other measures of constructional ability used in the study. Secondly, inspection of the individual data revealed that in fact only 3 children obtained scores on one of the 5 constructional task which fell above the 50th centile (2 children on the block design and one child on the Developmental Test of Visual-Motor Integration), leaving 9 children whose scores across all constructional tasks were generally depressed. Thirdly, the slow children did not differ from the fast children on any of the other measures including neurological status, general perceptuo-motor competence, manual dexterity, or vision. There was, however, an indication that the majority of the slow children had difficulty with one aspect of visual discrimination, i.e. correctly identifying the orientation of a shape (Matching Letter-Like Forms).

Having said this, individual differences were noted. Clear cut cases of selective impairment in constructional ability were relatively rare. There were only 3 slow children whose performance on all the tasks fell below the 25th centile. The constructional difficulties experienced by the remaining slow children, although obvious, were less extensive and their profiles showed different combinations of failure across the constructional tasks. In addition to being slow and inaccurate on the form boards, 4 children were also slow in constructing the block designs and one of the two pen-and-

paper tasks. A further 5 children did not have difficulty with the block designs but performed poorly on the graphic tasks.

Sometimes, poor vision seemed to co-occur with poor constructional ability. For example, Subject 3 who failed all tasks was noted to have poor near visual acuity and Subjects 4 and 9, whose profiles on the constructional tasks varied, were both found to lack stereoscopic vision. More strikingly, however, was the observation that there was a large number of children whose poor constructional ability co-occurred with problems of visual perception. Ten of the 12 slow children were poor at either visually matching the shapes of the MASH form board or the Matching Letter-Like shapes task of the BAS. Two children failed both these tasks. In Chapter 3 it was already discussed that an impairment of the processing of visual information may contribute to poor perceptuo-motor competence. Our findings, therefore, support the view that visual perceptual deficits are associated with poor constructional ability.

At other times, fine and/or gross motor impairments co-occurred with poor constructional ability. Although few in number, there were 4 children who had difficulty with the manual dexterity tasks included in the Movement ABC Test. In particular, they were inaccurate on the 'bicycle trail' and slow on the 'threading beads' items. Two of these latter children and 2 more children's gross motor performance was below a level expected for their age, and 2 other children showed a slight excess of minor neurological signs only. These results illustrate that for some children the observed constructional difficulties may stem from poor 'motor' control.

It was of interest to note that whereas none of the 5 children with a consistently normal ultrasound scan failed all constructional tasks, 3 of the 7 children who had shown abnormalities upon ultrasound examination did. Another observation which may be of interest was a slight preponderance of 'minor' ischaemic lesions. However, extent or severity of constructional problems at school age did not relate significantly to the presence of an abnormal ultrasound scan in the neonatal period (Fisher exact test; $p>.05$).

9.6.2 Poor performance on the MASH form board – what is the problem?

In this second section we focus exclusively on how children complete the MASH form board. First, we examine whether the performance of the slow children was more affected than that of the fast children when the initial orientation of the shapes was manipulated. Secondly, using video analysis, the performance of both groups of children was described in *qualitative* terms.

Results

a) Does a change in orientation of shapes exacerbate the problems of the slow children?

Whether the slow children were more affected by the experimental manipulation of the shapes of the MASH form board than the fast children was examined by an analysis on both the speed and accuracy with which the shapes were inserted in each of the three conditions. The data are depicted in Figure 9.4. The analysis on speed revealed a main effect of group ($F=6.19$, $df=1,22$; $p<.05$) and condition ($F=54.37$, $df=2,44$; $p<.0001$). There was no interaction between group and condition ($F=1.08$, $df=2,44$; $p>.05$). The mean time taken for the slow children was 15 (SD=7), 43 (SD=33), and 96 (SD=33) seconds in the 'normal', 'rotated' and 'turned' condition, respectively. The fast children took 10 (SD=4), 18 (SD=6), and 76 (SD=44) seconds to insert the shapes in these same conditions.

When the total number of errors were examined a similar picture emerged. The main effect of group approached significance ($F=3.94$, $df=2,44$; $p=.06$), while the main effect of condition did reach statistical significance ($F=12.30$, $df=2,44$; $p<.0001$). Again, the interaction between group and condition was not significant ($F=1.68$, $df=2,44$; $p>.05$).

Discussion

The slow children were not more affected in their performance by a change in the initial orientation of the shapes than the fast children. Group differences did not reach significance in any specific condition, although the slow children did show a tendency to be slower and inaccurate when inserting shapes which deviated from the orientation of the cavities. It was interesting to note, however, that whereas the profile across the three

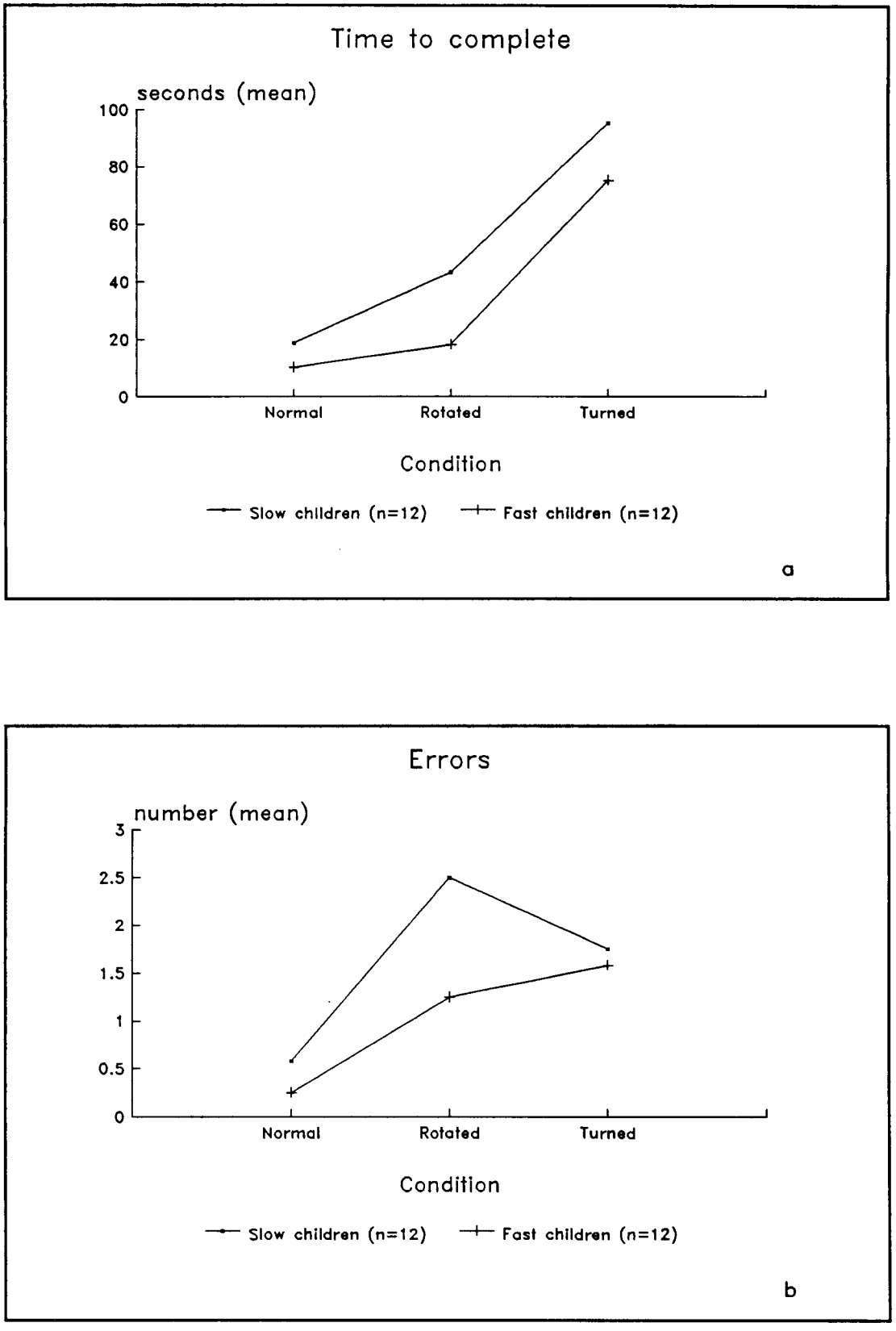

Figure 9.4: Mean time taken to complete (a) and number of errors (b) in three conditions of the MASH form board for the slow and fast children.

conditions for the fast children was similar to that found for all 6-year-old children (see Part 1 of this Chapter), the profile of the slow children indicated a tendency of increased difficulty with inserting the shapes in the 'rotated' condition.

Because a change of the orientation of the shapes did not clearly affect the performance of the groups in different ways it was decided to conduct a detailed qualitative analysis of performance on the original variant of the MASH form board task, i.e. when all 12 shapes were presented together to the child. The next section describes the procedure and results of this analysis.

b) Qualitative observations

Before the observers rated the video recordings it was decided to group the observations on the children's performance on the MASH form board under four broad categories. These categories were derived from long hand descriptions and notes of characteristics of performance made during testing of over 200 children by the author (MJ). By inspecting these and discussing them with the other raters (SH and LH), it was agreed that these four categories were sufficient to successfully capture all the individual comments made during the study. Inter-observer reliability on the overall classification of presence or absence of constructional problems (as judged by the two independent observers SH and LH) was good. In 17 out of the 23 children for whom a video recording was available agreement was reached (74%). In order to check intra-observer reliability, two observers (SH and MJ) rated performance of 4 matched pairs again after approximately one week (these descriptions are provided in Tables C.1a to C.1d in Appendix C). This time, all children were correctly classified. The sorts of observations that were to be included under each category are described below.

1) ***General behaviour***

When evaluating the speed and accuracy of performance on a task like the form board it is clear that a lack of interest or concentration from the part of the child should be taken into account. Observers were, therefore, asked to give their impression of the child's level of attention and concentration during the task.

2) *Strategy*

Children approach complex problems in different ways and the strategies they adopt can be described along different dimensions. Although these sometimes had to be inferred from more direct observations, on our form board task we agreed that the children differed from each other in several ways. For example, there were those who appeared to treat the insertion of each shape as a separate task, whereas others seemed to be able to merge one component into the other. In the latter case, for example, children could be seen to be approaching a new shape while still completing the insertion of the previous one. Also, there were systematic differences between the children in the way they organised the selection of shapes from the array. Some clearly had a strategy in mind whereas others appeared to pick up successive shapes randomly. These two examples should suffice to characterise the sort of observations that were made under this category.

3) *Transport/insertion of shapes*

As an estimate of the quality of dexterity, the observers described the way the child manipulated the shapes during the pick–up, transport, and insertion phase. For example, some children used only one hand throughout the task to pick up the shapes from the array and insert it into the cavities. Other children displayed bimanual manipulation and lifted the shape with one hand, transferred it to the other hand and then inserted it. Also, whereas some children clearly showed independent finger movements while manipulating a shape, others showed more immature patterns of prehension and 'clasped' the shape in their hand. In addition to the quality of dexterity, special attention was paid to whether the child preserved the orientation of the shape in the transport phase.

4) *Visual and haptic exploration/feedback*

Under this heading observers gave their judgement on how the child *appeared* to utilise the visual and haptic information available to him/her. During the pick up and transport phase attention was paid to whether the child was visually scanning the array, the shape once it was lifted and held in the hand, or the cavities. Also, the observers tried to rate the extent to which the child seemed to haptically explore the shape when holding and transporting it, and whether during the insertion phase there was any evidence of use of haptic feedback.

Tables 9.5a to 9.5l provide the combined qualitative descriptions of the 3 observers for each of the 12 matched pairs of slow and fast children [9]. To facilitate the overall picture of performance, a brief description of the profile of the slow child on the quantitative measures is given.

[9] *Numbering of pairs corresponds to the subject numbers in Table 9.4.*

Table 9.5a: Qualitative description of performance on the MASH form board for matched pair 1.

Slow child	Fast child
General behaviour wavering concentration, seems insecure **Strategy** -erratic approach in picking up shapes, hovering movements above pick up area -stop-and-search before inserting -random strategy for coping with errors, seems to be able to select shape from correct class of shapes but finds it difficult to vary output **Transport/insertion of shapes** -mostly unimanual, other hand only assists in time of difficulty -good, independent finger movements -some associated, fidgety movements in non-active hand -does not preserve orientation of shape in transport phase **Visual and haptic exploration/feedback** -does visually scan cavities and careful inspection of shape in hand -does not seem to act on haptic feedback	**General behaviour** good concentration, keen, 'hyped up' **Strategy** -able to dissociate eye and head movements from hand movements, i.e. 2 tasks at the same time: planning and execution -hovering movements of hand with shape over the board -no specific strategy in selection of shapes **Transport/insertion of shapes** -hurried, well directed, 'automatic' movements -bimanual coordination, not always effective **Visual and haptic exploration/feedback** -plenty of rapid visual scanning -some haptic exploration and after insertion of shape little 'tap' with hand on shape (haptic reassurance)
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- slow but accurate in completing block design
- poor human figure drawing
- poor manual dexterity
- poor shape discrimination
- poor ball skills

Table 9.5b: Qualitative description of performance on the MASH form board for matched pair 2.

Slow child	Fast child
General behaviour good concentration, no signs of frustration despite difficulties	**General behaviour** good concentration
Strategy -no systematic search of either shapes or cavities -many times maladaptive perseveration, does not seem to 'know' what to do when in difficulty	**Strategy** -seems as if strategy was planned ahead -sometimes picks up 2 shapes at a time -ability to dissociate actions, i.e. eye and head movements independent of hand movements
Transport/insertion of shapes -mostly unimanual -no preservation of orientation of shape in transport phase -slow hand movements -poor prehension, manipulation and insertion	**Transport/insertion of shapes** -fluent transport and insertion -bimanual coordination -dexterous but not exceptionally so -preserves orientation of shape in transport phase
Visual and haptic exploration/feedback -minimal visual scanning -poor use of haptic feedback	**Visual and haptic exploration/feedback** -rapid visual scanning of board but not of shape in hand -seems to pay attention to haptic information
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor on all constructional tasks - poor manual dexterity - poor visual discrimination (both shape and orientation)

Table 9.5c: Qualitative description of performance on the MASH form board for matched pair 3.

Slow child	Fast child
General behaviour good concentration **Strategy** -overall impression of hesitation and slowness -does not seem to evaluate own performance, i.e. no systematic adjustment for errors -initial attempt mostly incorrect **Transport/insertion of shapes** -bimanual manipulation sometimes efficient but most of the time malign -does not preserve orientation of shape in transport phase -no clumsy finger movements **Visual and haptic exploration/feedback** -intent visual inspection of shape in hand but scattered scanning of board -failure to act upon haptic feedback	**General behaviour** alert **Strategy** -seems 'expert' -eye and head movements ahead of movements of the hand -picks up 2 shapes at a time and is able to cope **Transport/insertion of shapes** -unimanual -transport of shape swift and fluent -preserves orientation of shape during transport **Visual and haptic exploration/feedback** -visual inspection both of pick-up area and cavities in board but not of shape itself
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor on all constructional tasks - poor near visual acuity

Table 9.5d: Qualitative description of performance on the MASH form board for matched pair 4.

Slow child	Fast child
General behaviour relative good concentration but distractible while transporting shape **Strategy** -no apparent shape selection -eye and head movements simultaneous with hand movements -hovering movements of hand with shape over the board **Transport/insertion of shapes** -does not preserve orientation of shape in transport phase -dexterous while shape is in hand (e.g. flicks it over) but clumsy finger movements when inserting the shape in cavity -to start with unimanual but when difficulties arise other hand involved as well **Visual and haptic exploration/feedback** -great deal of visual scanning of cavities but poor: does not act upon mis-match, only notices that shape is inserted in wrong cavity when encountering its 'twin' (e.g. confuses the two houses)	**General behaviour** alert **Strategy** -systematic approach -eye and head movements separate from hand movements, i.e. eye and head movements ahead of hand movements to search for cavity in board -hovering movements of hand with shape over the board **Transport/insertion of shapes** -independent finger movements -very bi-manual; hands co-operate well with each other -fast, fluent transport phase **Visual and haptic exploration/feedback** -good; actions seem totally visually driven, keeps checking position of shape and cavity -after insertion other hand 'taps' shape (haptic reassurance)
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- slow on the block designs
- poor human figure drawing
- poor shape discrimination
- no stereoscopic vision

Table 9.5e: Qualitative description of performance on the MASH form board for matched pair 5.

Slow child	Fast child
General behaviour good concentration	**General behaviour** alert, keen
Strategy -seems to be aware of pairs of shapes but unsystematic approach -perseveres in wrong attempts	**Strategy** -picks up shapes systematically, starting at top left-hand corner and finished at bottom right-hand corner of pick up area -swift adaptation to error -hovering movements of hand with shape over the board
Transport/insertion of shapes -hesitant, not fluent transport phase -clumsy finger movements while inserting shape -no preservation of orientation of shape in transport phase -mostly unimanual	**Transport/insertion of shapes** -dexterous and neat movements -fluent, undisturbed sequence -almost always preserves orientation of shape in transport phase -mostly unimanual
Visual and haptic exploration/feedback -does visually scan pick up area and cavities but not shape in hand -seems unable to operate on visual or haptic feedback	**Visual and haptic exploration/feedback** -swift visual inspection of cavities
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- slow and inaccurate on block design
- poor shape copying
- poor manual dexterity
- poor shape discrimination
- poor ball skills

Table 9.5f: Qualitative description of performance on the MASH form board for matched pair 6.

Slow child	Fast child
General behaviour good concentration but seems to lack confidence	**General behaviour** alert
Strategy -does not seem to be a good problem solver -perseveres in implausible attempts -eye, head and hand movements in synchrony	**Strategy** -well organised -deals with complicated shapes first
Transport/insertion of shapes -lacks fluency -mixture of unimanual/bimanual clumsy manipulation -misalignment of shape when inserted because of change of orientation in transport phase -insertion slightly awkward	**Transport/insertion of shapes** -smooth transport of shape -mainly unimanual -eye and head movements ahead of hand movements -excellent preservation of orientation of shape in transport phase -neat insertion
Visual and haptic exploration/feedback -plenty of visual scanning but apparently inefficient -extra 'tap' on shape after insertion (haptic reassurance)	**Visual and haptic exploration/feedback** -good visual searching -does not seem to depend on haptic feedback
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor on both graphic skills
- poor discrimination of orientation of shape
- minor abnormal neurological signs

Table 9.5g: Qualitative description of performance on the MASH form board for matched pair 7.

Slow child	Fast child
General behaviour good concentration throughout **Strategy** -slow, deliberate style -some evidence of selection: picks up shapes in pairs initially (i.e. cross 1 followed by cross 2 and same with stars pair) -hovering movements of hand both above pick-up area as well as board **Transport/insertion of shapes** -hesitant, though neat movements -left hand used at first but right hand takes over when in difficulty -awkward finger movements at point of insertion (OBS 2: no awkward finger movements) **Visual and haptic exploration/feedback** -visual driven attempts at rotating shape and sensible selection of alternative cavities -no apparent haptic exploration of shape but after insertion other hand 'taps' shape (haptic reassurance)	**General behaviour** alert **Strategy** -complete sequence, i.e. starts with picking up shape at top left-hand corner and finishes with shape at bottom right-hand corner of pick-up area **Transport/insertion of shapes** -fluent sequential movements -dexterous; neat transportation and insertion -preserves orientation of shape while transporting -goes fast towards end **Visual and haptic exploration/feedback** -systematic visual search of cavities in board
Observer 1: slow child Observer 2: fast child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor graphic skill (human figure drawing only)
- poor discrimination of orientation of shape
- minor abnormal neurological signs

Table 9.5h: Qualitative description of performance on the MASH form board for matched pair 8.

Slow child	Fast child
General behaviour good concentration **Strategy** -no effective search strategy -initially chooses sensible alternatives but when in difficulty seems to settle for lesser solutions -spends a lot of time with shape in hand while scanning board **Transport/insertion of shapes** -fluent movements -good manipulation -difficulty with turning shape in depth but not picture plane **Visual and haptic exploration/feedback** -plenty of visual scanning of board, but seemingly inefficient -does not use haptic feedback	**General behaviour** good concentration **Strategy** -looks well organised -eye and head movements ahead of hand movements -constant monitoring of situation **Transport/insertion of shapes** -controlled, fluent movements -finger movements precise and insertion neat -unimanual -sometimes fails to preserve orientation of shape in transport phase -overshoot of target (last visual check?) **Visual and haptic exploration/feedback** -visually driven behaviour -'tapping' of shape after insertion (haptic reassurance)
Observer 1: slow child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor shape copying

Table 9.5i: Qualitative description of performance on the MASH form board for matched pair 9.

Slow child	Fast child
General behaviour good concentration but seems insecure of actions **Strategy** -'narrow minded' strategy, i.e. does not seem to be able to consider more than one object at a time -no systematic approach **Transport/insertion of shapes** -to start with many trials fluent but from the moment the problems arise more awkward attempts -strongly unimanual; relatively agile hand and finger movements -preservation of orientation of shape in transport phase not too bad **Visual and haptic exploration/feedback** -does not seem to appreciate subtle differences between the shapes: tolerates mis-match twice, i.e. does not correct immediately -performance mainly visually driven -no obvious use of haptic feedback	**General behaviour** good concentration **Strategy** -slow, unhurried in style -not an efficient search strategy but compensates by ability to correct errors fast -pre-decided destination of shape once lifted from the pick-up area -deals with complicated shapes first **Transport/insertion of shapes** -careful in manipulation -orientation of shape well preserved in transport phase -strongly unimanual -goes faster towards end **Visual and haptic exploration/feedback** -good visual discrimination
Observer 1: fast child Observer 2: slow child	Observer 1: slow child Observer 2: fast child

Quantitative profile
- poor on all constructional tasks
- poor discrimination of orientation of shape
- no stereoscopic vision

Table 9.5j: Qualitative description of performance on the MASH form board for matched pair 10.

Slow child	Fast child
General behaviour good concentration throughout	**General behaviour** keen, good concentration (tong protrusion)
Strategy -erratic, random strategy -perseveres in attempts to insert in wrong cavity	**Strategy** -seems to adapt well to the problem presented, few wrong attempts -no obvious strategy for picking up shapes
Transport/insertion of shapes -initially does not preserve orientation of shape in transport phase, later on better -no clean insertion of shape; needs slight rotation each time -bimanual; hands used for different activities	**Transport/insertion of shapes** -swift, smooth, careful movements -does not always preserve orientation of shape in transport phase -unimanual
Visual and haptic exploration/feedback -limited visual scanning of board, none of shape in hand -does not seem to use haptic feedback appropriately	**Visual and haptic exploration/feedback** -seems to rely mostly on visual feedback and exploration
Observer 1: fast child Observer 2: slow child	Observer 1: fast child Observer 2: fast child

Quantitative profile
- poor in graphic skills (human figure drawing only) - poor shape discrimination

Table 9.5k: Qualitative description of performance on the MASH form board for matched pair 11.

Slow child	Fast child
No video available	**General behaviour** alert, confident **Strategy** -'intelligent' approach although no obvious strategy of picking up shapes -seems to know where shape should be inserted from moment of pick-up **Transport/insertion of shapes** -controlled, fluent transport of shapes -well coordinated insertion -preserves orientation of shape in transport phase throughout -unimanual **Visual and haptic exploration/feedback** -good scanning of the board -good visual feedback, i.e. swift error correction -seems to use haptic feedback
	Observer 1: fast child Observer 2: fast child

Quantitative profile
- slow on block designs
- poor shape copying
- poor manual dexterity
- poor visual discrimination (both shape and orientation)
- minor abnormal neurological signs

Table 9.5l: Qualitative description of performance on the MASH form board for matched pair 12.

Slow child	Fast child
General behaviour good concentration	**General behaviour** good concentration energetic, impulsive
Strategy -pre-decided actions -perseveres in wrong attempts; no reconsideration of strategy -careful approach; does seem to thing about what he is doing	**Strategy** -no evident search strategy -seems lucky with some attempts
Transport/insertion of shapes -bimanual manipulation -neat insertion when shape is recognised, otherwise not dexterous -rotates shapes both through picture plane or depth plane	**Transport/insertion of shapes** -unimanual -initially clumsy (athetoid type) movements of the fingers but settles down later -associated movements of other hand and face
Visual and haptic exploration/feedback -plenty of visual scanning but suspected poor visual discrimination (tunnel vision) -poor use of haptic feedback	**Visual and haptic exploration/feedback** -visual inspection of shape in hand and cavities in board -haptic exploration
Observer 1: fast child Observer 2: slow child	Observer 1: slow child Observer 2: fast child

Quantitative profile
- poor on both graphic skills
- poor discrimination of orientation of shape
- poor balance

Overview of qualitative analysis

Observations of the quality of performance on the MASH form board showed that most of the slow children could easily be distinguished from the fast children but that the differences between pairs varied considerably. The qualitative observations are summarised below and related to the 'perceptual', 'motor' and overall 'strategy' aspects of performance.

General behaviour

Except for 2 slow children, all seemed to sustain a good level of concentration throughout the task. However, the behaviour of 3 slow children including one with ambiguous concentration was judged as lacking confidence, for example, often glancing at experimenter as if looking for approval of actions. In contrast, words as 'keen' and 'alert' were frequently used to describe the overall level of attention among the fast children.

Strategy

The way in which the child selected the shapes from the pick–up area seemed to separate the slow and fast children well. In 7 slow children it did not look as if they were selecting the shapes in any systematic manner. In contrast, 8 fast children were noted to start with the shape at the top left–hand corner of the pick–up area and finished with the shape situated in the bottom right–hand corner or, alternatively, there was some evidence that shapes were selected on the basis of similarity (e.g. cross 1 and cross 2, etc.). Only 2 slow children showed some evidence of systematic shape selection. For example, slow child number 12 was described as appearing to show 'pre–decided actions', 'careful' in his approach as if he 'seemed to think about what he is doing'. Interestingly, he was classified by one of the observers as belonging to the competent group and obtained the highest verbal ability score of all slow children.

It was of interest that, although most slow children showed a non–systematic approach, the 3 children (Ss 2, 3, and 9) who failed all constructional tasks seemed exceptionally poor in structuring their approach towards the task. In addition, although observer 1 did eventually classify one of these children (Ss 9) as belonging to the competent group, all observers agreed that these 3 children showed evidence of an impairment in the

'perceptual' components of the task. In contrast, just one child was judged as inept on the 'motor' component of the task (i.e. quality of manipulation).

Close inspection of the movements of those children who were described as 'efficient' or 'well organised' revealed that they were able to coordinate their eye–, head–, and hand–movements well. From the moment the shape was lifted from the pick–up area, the eyes and head moved immediately to the board to visually scan the cavities while the hand lagged behind to actually lift the shape. Once the cavity was found it looked as if the hands again worked independently of the visual system as they finished the task of insertion by themselves and, while inserting, the eyes and head already went back to the pick–up area to select the next shape. In contrast, in many of the slow children the eye–, head–, and hand–movements looked synchronous. In other words, the movements of the hand were visually guided both while lifting and inserting the shapes.

Transport/insertion of shapes

Awkward insertion of the shapes into the cavities was noted in 6 slow and 1 fast child. Sometimes it was observed that this was associated with an apparent absence of independent finger movements. In comparison, neat insertion was more frequently noted among the fast children. The number of slow children who were unimanual, bimanual or who alternated between using one or two hands, was equal. In contrast, the great majority of the fast children used one hand and only some were bimanual in their manipulation of the shapes when they were having slight difficulty in locating the correct cavity. For some slow children it was observed that the movements during the transport phase lacked fluency and looked awkward.

One observation which seemed to differentiate the quality of performance of the slow children from that of the fast children well, was 'preservation of orientation of shape in transport phase'. The descriptions of 7 slow children included a comment that they failed to do so, while this was only noted in 2 of the fast children. Although this could be a result of 'clumsy' manipulation by the slow children, it is equally likely that the slow children were less aware of the importance of the orientation of the shape in order to successfully insert it.

The use of visual and haptic exploration/feedback

Initially, one might hypothesise that children who have difficulty locating the correct cavity and/or inserting a shape might need to look more carefully before beginning the task. Also, after a wrong attempt the child needs to consider alternative cavities by scanning the board. However, visual exploration of the shapes was rarely observed either among the slow or fast children. Only 3 children in each group deliberately looked at the shape while it was in their hand. In contrast, it was more common to observe that children were visually scanning the cavities in the board. Although the frequency of this observation was similar for the two groups, it was often commented when watching the slow children that they did not seem to benefit from this visual inspection. In contrast, the behaviour of the fast children was frequently described as 'visually driven'.

Similarly, it may be expected that children who have difficulty with the form board task would need to 'feel' the shapes as an extra source of information in guiding their actions. Although haptic exploration/feedback was a difficult category of performance to rate, two observations serve to demonstrate the way the children made use (or not) of haptic information. Exploration of the shapes with the fingers was rarely observed (i.e. few children turned the shapes or showed evidence of exploring the edges of the shapes). However, it was sometimes noted that after having inserted the shape, the child gave a little tap with either hand on the shape which could be interpreted as a form of 'haptic reassurance'. This behaviour was observed in 5 fast versus 2 slow children.

Observations of incorrectly classified children

The qualitative profiles of the 4 children who were judged as being competent at inserting the shapes in the form board, but who were actually slow, were examined in more detail to investigate whether they shared a common feature which divided them from the other (correctly identified) slow children. From this comparison it appeared that it was not possible to identify one particular category of performance which separated these children from the other slow children. In general, however, the observation that they preserved the orientation of the shape in the transport phase and were tidy in the insertion phase may have led to the mis-classification.

One of the 2 children who was rated as belonging to the slow group, but whose time to complete the form board actually compared favourably to that of the reference children, was described as unhurried in her movements and lacked a clear strategy. The other child's performance was also described as lacking a clear strategy. In addition, clumsy finger movements, and some associated movements of the face and other hand were observed.

Discussion

Few studies exist which provide both quantitative and qualitative data on the problems children encounter when performing a perceptuo-motor action. As far as we can determine, there are only two other studies which have embarked upon the same enterprise using either a different or similar task. The first study (Barnett, 1992) documented the characteristics of performance of 'clumsy' children on a buttoning and peg board task and in the second study by Kalverboer and Brouwer (1983) children were asked to complete a constructional task similar to that employed in the present study. The results of both of these studies are discussed in relation to our own findings.

Barnett (1992) described the quality of performance on a peg insertion and buttoning task by 'clumsy' children aged between 5 and 12 years. As the peg insertion task was the most comparable to our own task only the findings on these will be briefly discussed. Performance was rated in 5 categories: motor control, motor overflow, spatial errors, force errors and other errors. The most frequently observed characteristics of the 'clumsy' children consisted of poor trunk and head posture, poor grip, lack of fluent movements, exaggerated movements when releasing the peg, misaligning the peg with respect to the hole, excessive use of force when inserting the peg, and dropping the peg. Barnett also analyzed the data for different age-groups. The older children showed noticeably better performance in their posture of the trunk and head, grip, alignment of the peg with respect to the holes in the board, and had a lower frequency of dropping the pegs. In contrast, a lack of smoothness of movements was observed irrespective of age. When the children were assessed again after 18 months, most had improved their performance although many were still judged as exhibiting movements which lacked smoothness and looked odd, and several observations which had previously not been observed were now present in some

children.

Some similarities emerged between Barnett's and our study. For example, some of the slow children in the present study showed similarly awkward movement patterns which lacked fluency and smoothness. Also, misalignment of the shape with regard to the cavity was frequently observed. However, as Barnett's results suggest, it may be that these difficulties in performance are age related with some diminishing in frequency to give way to others.

The most interesting study with respect to the present one, was conducted by Kalverboer and Brouwer (1983) who observed the behaviour of children between 4 and 5 years of age on a task in which the children were required to insert blocks of different shapes into identical shaped holes in a box. Each child completed 7 trials in either a self-paced or time-pressure condition. From video recordings, observers rated the child's performance in 20 categories. The results of these analyses could be summarized as follows.

First, in the time-pressure condition the total time taken to insert the blocks was significantly lower than when the task was self-paced, whereas the number of 'errors of judgement' (such as misplacements, corrections at grasping and strong deviations at insertion) did not change significantly. Second, in most categories the frequencies of 'faults' was higher in the first than in the remaining 6 trials indicating that the learning process was nearly completed after the first trial. Third, the interrelationships between the categories was similar in each of the 7 trials demonstrating consistency of organisation of behaviour irrespective of the task requirements (i.e. self-paced or paced conditions). Fourth, 5 categories seemed particularly sensitive to the effects of time-pressure and were more frequently observed in the paced than self-paced trials. These were 'minor deviations at insertion', 'tapping' (the top of the box after the block was inserted), 'arm and trunk movements', 'distraction' (interruption in the activity), and 'additional movements'. Finally, fast performance was characterised by an improvement in the processes of selection and comparison of blocks during the execution of the task.

Several of the observations made in the present study correspond to those recorded by

Kalverboer and Brouwer (1983). For example, the change in orientation when transporting the blocks leading to a subsequent minor or major deviation at insertion was common to both studies. It could be argued that the orientation of the shape during the transport phase changes as a result of 'clumsy' manipulation (or grasp), or as a result of not being able to appreciate the relationship between the orientation of the shape and the orientation of its corresponding cavity. Earlier in the present study it was noted that some of the slow children clearly found it difficult to insert those shapes who had been presented in a 'rotated' orientation. Furthermore, we observed that the slow children were worse than the fast children in identifying the correct shape from an array of shapes varying only in orientation. Taking all these observations into account, it seems that the inability to match the orientation of the shape to that of the cavity is a major determinant of poor performance for some, but not all, children with constructional difficulties.

Another similar observation between the studies was that some children 'tapped' the shapes after they were inserted. Kalverboer and Brouwer noted that this behaviour was more frequently observed when the children worked under time-pressure than when they could insert the blocks in their own time. As we suggested before, the significance of these 'tapping' movements may lie in providing the child feedback about the success of insertion.

A final striking resemblance between our study and that of Kalverboer and Brouwer was that the strategy adopted by the child in selecting the blocks/shapes was a major determinant of fast and successful performance. This observation suggests that the more a child plans its movements ahead of the action, the more successful he or she will be in completing the task within a short time span. The results of the present study suggest that observing the quality of the coordination of a child's eye-, head-, and hand movements may be a way of operationalising this component of performance.

9.7 Conclusion

In part 2 of this Chapter, we have addressed two questions: 1) does constructional dyspraxia exist among premature children? and 2) what characterises the performance of children whose difficulty to complete the form board tasks is in sharp contrast to their

performance on other perceptuo-motor tasks? Our conclusions are outlined below.

Constructional dyspraxia

The results of this study provide support for the existence of children whose performance on constructional tasks is poorer than that on other types of perceptuo-motor tasks. Even though in some of these children other problems co-occurred (e.g. poor visual perception) we felt that these were not sufficient to account for the specific constructional problems observed in any child. Examination of profiles of the children's strengths and weaknesses demonstrated that there was individual variation in the extent and severity of constructional difficulties.

What should be kept in mind, however, that also children with difficulties change as they grow older. They do acquire new skills and their ability to cope with problems changes. However, today little information is available regarding even the 'normal' development of children's ability to perform constructional tasks. On the one hand it may be that the children described here are simply slower than others in acquiring this particular class of skill and will eventually 'catch up'. On the other hand, however, Barnett's (1992) results seem to suggest that although these children may improve with age, certain characteristics of their performance may be resistant to progress. Moreover, previously unnoted characteristics may emerge. Therefore, only a longitudinal follow-up study can establish whether the observed difficulties of the slow children at 6 years of age are still present later in life.

Describing performance on a form board task - the added value of qualitative observations

Although measures of slowness and inaccuracy are reliable indicators of impairment in the execution of a task they are limited in what they can tell about other, equally important, aspects of performance which may contribute to a child's problems. Descriptions such as those provided in this study on how the children seemed to plan their actions, the sequence in which they performed the task, and the use of feedback may lead to the generation of more specific hypotheses regarding the underlying processing deficits. In particular, because 'constructional dyspraxia' is hypothesised to be related to an

impairment in the planning of the movements only qualitative data provide insight into this aspect if behaviour. Future studies investigating the nature and extent of perceptuo–motor problems, including constructional dyspraxia should, in combination with the quantitative outcome measures, consider including an analysis of quality of performance to come to a better description and understanding of children's difficulties.

CONCLUSIONS

The aim of the present study was to examine perceptuo-motor competence at 6 years of age among a cohort of children born before 35 weeks of gestation. The neonatal status of these children was well documented, including detailed neurological assessment and ultrasound examination. Compared to studies which combine data across hospitals which provide varying routine medical care, the advantages of the present study lie in the uniform level of neonatal intensive care received by the children and the fact that all ultrasound data were evaluated by one examiner. However, the disadvantage of this study lies in the restricted application of the findings to the general population of prematurely born infants as admission to the Hammersmith hospital is selective and follow up was restricted to children for whom adequate ultrasound data was available. The findings of the study can be summarised under four headings.

Brain lesions: their association with later perceptuo-motor competence

The present study has been able to shed more light on the association between the presence of a brain lesion in the neonatal period and perceptuo-motor competence at 6 years of age. Our findings confirm those of other studies that a consistently normal ultrasound scan appears to be associated with good outcome. Nevertheless, some children with normal scans were poorly coordinated and/or of lower cognitive ability than the reference children. The development of children with 'major' lesions is undoubtedly still a cause for concern, although our findings indicate that children with such lesions (particularly of haemorrhagic nature) do not invariably develop major physical and/or mental impairments. 'Minor' lesions were not found to be associated with severe developmental problems but this study has shown that children with such lesions are likely to experience perceptuo-motor difficulties of lesser severity. Moreover, our data suggest that there may be systematic differences in the pattern of impairment shown by different groups. Therefore, children with 'minor' lesions such as flares warrant further evaluation.

This study has confirmed previous reports that brain lesions may be found in some but not necessarily in all children with perceptuo-motor problems. Why interindividual

differences in outcome exist among children without a brain lesion or among children who have apparently similar brain lesions is still not well understood. Our knowledge about morphological plasticity in the human is still rudimentary and we can only speculate on the 'recovery' processes that took place in the brains of children who did surprisingly well following a 'major' lesion in the neonatal period. Similarly, studies of how children gradually learn to 'compensate' for their impairment in daily life have, to our knowledge, not yet been conducted. Other investigative techniques such as near–infra–red spectroscopy or Positron Emission Tomography, although not widely used today, may in the future provide insight into the developmental changes in metabolic and circulatory processes occurring in different regions of the brain and allow a more detailed comparison between neurophysiological and behavioural changes that occur over time.

Individual variation in the nature of perceptuo–motor problems

In contrast to previous follow up studies which were mainly concerned with documenting global outcome of prematurely born children, the present study has provided a detailed account of perceptuo–motor abilities. The problems experienced by the children in our cohort ranged from an identifiable central motor deficit to 'clumsiness'. Although the majority of children with perceptuo–motor problems (not identified as having a central motor deficit) showed a range of difficulties there were children whose difficulties seemed to be more specific. To determine this, identification of the child with perceptuo–motor problems has to go beyond examination of total scores, and should include an investigation of a child's strengths and weaknesses in a wide range of areas. Based on performance on a variety of assessments we were able to show that the group of children who had perceptuo–motor problems in the present study could be further sub–divided into smaller groups which each showed different profiles of performance across tasks. Although recently reports have started to appear in the literature describing distinct patterns of behaviour among children born 'at risk' within the cognitive domain, the present study is one of the few which has looked for the existence of diverse patterns of behaviour within the perceptuo–motor domain. We have shown that identification of dissociations in perceptuo–motor ability can be achieved by applying a combination of descriptive and statistical techniques. More attempts should now be directed towards understanding the processes involved in the execution of perceptuo–motor tasks within

individual children.

In this thesis, an example was also presented of the way in which a detailed analysis of individual variability in performance can be accomplished. Having identified a small sub-group of children who showed specific difficulty with constructional skills, a systematic examination of the characteristics of these children compared to a group of children who did not have constructional problems was conducted. Supplementing the individual quantitative profiles with detailed descriptions of the way each child completed the task proved a valuable tool in beginning to understand the contribution of various processes to poor performance in the individual child. Although we recognise that such detailed quantitative and qualitative analyses as carried out in the present study are difficult to incorporate in large scale follow up studies, we recommend that additional studies of smaller groups of premature children addressing specific hypotheses regarding the nature and severity of perceptuo-motor problems are undertaken in the future.

The outlook for children with perceptuo-motor problems

The implications of our findings for the future development of the premature children identified as having perceptuo-motor problems at 6 years of age are not yet clear because no studies have been able to follow children who were beneficiaries of modern neonatal care beyond the primary school years. However, previous studies which examined children identified as having coordination problems in their early school years and again as adolescents almost invariably report that many continue to experience not only perceptuo-motor but also social and academic problems into adolescence. We suspect, therefore, that the outlook for some of the children who participated in the present study will remain a cause for concern, especially for those who consistently performed below average across a range of perceptuo-motor tasks and already showed concomitant problems. It is thus essential to continue efforts to identify children with perceptuo-motor problems at an early age in order to attempt prevention of the primary and secondary problems that may arise in later years.

The need for longitudinal studies/care of the premature child

Our findings strongly support the continued need for carefully monitoring the development

of modern neonatal intensive care graduates. As evidence accumulates that some premature children who appear to develop 'normally' within the first 3 years show subtle difficulties at a later age it becomes clear that the results of short-term studies are of limited value and may even be misleading. Moreover, as the children in our cohort have only just started school it is possible that due to the increasing demands placed upon them by the environment, the incidence of children experiencing problems may increase even further. Although longitudinal studies are expensive and time consuming to conduct, we have shown that the information obtained by such studies is a vital source of feedback for those professionals involved in caring for the child in the neonatal period as well as for the parents and teachers involved in the current and future care of these children. It is imperative to extent the support to the child and its parents beyond the neonatal intensive care unit into the pre-school and school years.

REFERENCES

Abercrombie, M.L.J., Lindon, R.L., Gardiner, P.A., Solomon, G., Hansen, E., Jonckheere, J. & Tyson M.C. (1964). Visual, perceptual and visuomotor impairment in physically handicapped children. Perceptual and Motor Skills, 18, 563–625.

Abel–Smith, A.E. & Knight–Jones, E.B. (1990). The abilities of very low–birthweight children and their classroom controls. Developmental Medicine and Child Neurology, 32, 590–601.

Achenbach, T.M. & Edelbrock, C. (1983). Manual for the Child Behavior Checklist and Revised Child Behavior Profile. Burlington, VT: University of Vermont.

Adler, H. (1982). Children with problems in physical education in school II. Physical factors and psychosocial problems. Acta Paedopsychiatra, 48, 33–46.

Alberman, E.D. (1984). Describing the cerebral palsies: methods of classifying and counting. In F. Stanley and E.D. Alberman (Eds.), The epidemiology of the cerebral palsies. Clinics in Developmental Medicine, 87. London: Spastics International Medical Research.

Amiel–Tison, C., Dube, R., Garel, M. & Jequier, J.C. (1983). Outcome at age 5 years of fullterm infants with transient neurological abnormalities in the first year of life. In L. Stern (Ed.), Intensive care IV. New York: Masson.

Amiel–Tison, C. & Grenier, A. (1986). Neurological assessment during the first year of life. New York: Oxford University Press.

Anderson, E.M. & Spain, B. (1977). The child with spina bifida. London: Methuen & Co.

Appleton, R.E., Lee, R.E.J. & Hey, E.N. (1990). Neurodevelopmental outcome of transient neonatal intracerebral echodensities. Archives of Disease in Childhood, 65, 27–29.

Astbury, J., Orgill, A. & Bajuk, B. (1987). Relationship between two–year behaviour and neurodevelopmental outcome at five years of very low–birthweight survivors. Developmental Medicine and Child Neurology, 29, 370–379.

Astbury, J., Orgill, A.A., Bajuk, B. & Yu, V.Y.H. (1990). Neurodevelopmental outcome, growth and health of extremely low–birthweight survivors: How soon can we tell? Developmental Medicine and Child Neurology, 32, 582–589.

Aylward, G.P., Gustafson, N., Verhulst, S.J. and Colliver, J. (1987). Consistency in the diagnosis of cognitive, motor and neurological function over the first three years. Journal of Pediatric Psychology, 12, 77–98.

Aylward, G.P. & Pfeiffer, S.I. (1989). Follow-up and outcome of low birthweight infants: conceptual issues and a methodology review. Australian Pediatric Journal, 25, 3-5.

Ayres, J,A., Mailloux, Z.K. & Wendler, C.L.W. (1987). Developmental dyspraxia: Is it a unitary function? Occupational Therapy Journal of Research, 7, 93-110.

Baird, H. & Gordon, E.D. (1983). Neurological evaluation of infants and children. London: The Lowenham Press Ltd.

Bairstow, P.J. & Laszlo, J.I. (1981). Kinaesthetic sensitivity to passive movements and its relationship to motor development and motor control. Developmental Medicine and Child Neurology, 23, 606-616.

Banker, B.Q. & Larroche, J-C. (1962). Periventricular leukomalacia of infancy: a form of neonatal anoxic encephalopathy. Archives of Neurology, 7, 386-410.

Barnett, A.L. (1992). Manual competence in clumsy children. Doctoral thesis, University of London, England.

Barnett, A.L. & Henderson, S.E. (1992). Some observations of the figure drawings of clumsy children. British Journal of Educational Psychology, 62, 341-355.

Bax, M. (1964). Terminology and classification of cerebral palsy. Developmental Medicine and Child Neurology, 6, 295-297.

Bax, M. & Whitmore, K. (1973). Neurodevelopmental screening in the school-entrant medical examination. Lancet, ii, 368-370.

Bax, M. & Whitmore, K. (1987). The medical examination of children on entry to school. The results and use of neurodevelopmental assessment. Developmental Medicine and Child Neurology, 29, 40-55.

Bayley, N. (1969). Manual for the Bayley Scales of Infant Development. New York: The Psychological Corporation.

Beery, K.E. (1982). Developmental Test of Visual-Motor Integration. Cleveland, OH: Modern Curriculum Press.

Bender, L. (1938). The Visual Motor Gestalt test and its clinical use. New York: The American Orthopsychiatric Association.

Benton, A.L. (1940). Mental development of prematurely born children. A critical review of the literature. American Journal of Orthopsychiatry, 10, 719-746.

Birch, H.G. & Lefford, A. (1967). Visual differentiation, intersensory integration and voluntary motor control. Society for Research in Child Development Monograph, 32, No. 2.

Black, B., Brown, C. & Thomas, D.A. (1977). A follow-up study of 58 preschool children less than 1500 grams birthweight. Australian Paediatric Journal, 13, 265-270.

Blackman, J.A., Lindgren, S.D., Hein, H.A. & Harper, D.C. (1987). Long-term surveillance of high risk children. American Journal of Disease in Childhood, 141, 1293-1299.

Blair, E. & Stanley, F. (1985). Interobserver agreement in the classification of cerebral palsy. Developmental Medicine and Child Neurology, 27, 615-622.

Bradley, R.H. & Casey, P.H. (1992). Family environment and behavioral development of low-birthweight children. Developmental Medicine and Child Neurology, 34, 822-825.

Broadhead, G.D., Maruyama, G.M. & Bruininks, R.H. (1985). Examining differentiation in motor proficiency through exploratory and confirmatory factor analysis. In J.E. Clark & J.H. Humphrey (Eds.), Motor development: Current selected research (Vol. 1). Princeton Book Company.

Brothwood, M., Wolke, D., Gamsu, H., Benson, J. & Cooper, D. (1986). Prognosis of very low birthweight baby in relation to gender, Archives of Disease in Childhood, 61, 559-564.

Bruce, V. & Green, P.R. (1990). Visual perception: Physiology, psychology and ecology (2nd Edition). London: Lawrence Erlbaum.

Bruininks, R.H. (1978). The Bruininks-Oseretsky Test of Motor Proficiency. Circle Pines, MN: American Guidance Service.

Bundy, A.C. & Fisher, A.G. (1992). Evaluation of sensory integration dysfunction. In H. Forssberg & H. Hirschfeld (Eds.), Movement disorders in children. Basel: Karger.

Calame, A., Fawer, C.L., Claeys, V. et al. (1986). Neurodevelopmental outcome and school performance of very low-birthweight infants at 8 years of age. European Journal of Pediatrics, 145, 461-466.

Calvert, S.A., Hoskins, E.M., Fong, K.W. & Forsyth, S.C. (1987). Etiological factors associated with the development of periventricular leukomalacia. Acta Paediatrica Scandinavia, 76, 254-259.

Casaer, P. (1993). Old and new facts about perinatal brain development. Journal of Child Psychology and Psychiatry, 34, 101-109.

Casaer, P., De Vries, L. & Marlow, N. (1991). Prenatal and perinatal risk factors for psychosocial development. In M. Rutter and P. Casaer (Eds.), Biological risk factors for psychosocial disorders, Cambridge: Cambridge University Press.

Catto-Smith, A.G., Yu, V.Y.H., Bajuk, B., Orgill, A.A. & Astbury, J. (1985). Effect of neonatal periventricular haemorrhage on neurodevelopmental outcome. Archives of Disease in Childhood, 60, 8-11.

Cermak, S. (1985). Developmental dyspraxia. In E.A. Roy (Ed.), Neuropsychological studies of apraxia and related disorders (Advances in Psychology, 23). Amsterdam: Elsevier Science Publishers.

Chen, M.J. & Freeman, N.H. (1984). Orientation of the diamond and the square revisited. Australian Journal of Psychology, 36, 327-335.

Chugani, H.T., Phelps, M.E. & Mazziotta, J.C. (1993). Positron emission tomography study of human brain functional development. In M.J. Johnson (Ed.), Brain development and cognition: A reader. Oxford: Blackwell.

Cioni, G., Bartalena, L., Biagioni, E., Boldrini, A. & Canapicchi, R. (1992). Neuroimaging and functional outcome of neonatal leukomalacia, Behavioural Brain Research, 49, 7-19.

Cooke, R.W.I. (1987). Early and late cranial ultrasonographic appearances and outcome in very low birthweight infants. Archives of Disease in Childhood, 62, 931-937.

Costello, A.M. de L., Hamilton, P.A., Baudin, J., Townsend, J., Bradford, B.C., Stewart, A. & Reynolds, E.O.R. (1988). Prediction of neurodevelopmental impairment at four years form brain ultrasound appearance of very preterm infants. Developmental Medicine and Child Neurology, 30, 711-722.

Crowe, T.K., Deitz, J.C., Bennett, F.C. & TeKolste, K. (1988). Preschool motor skills of children born prematurely and not diagnosed as having cerebral palsy, Journal of Developmental and Behavioural Pediatrics, 9, 189-193.

Dare, M.T. & Gordon, N. (1970). Clumsy children: A disorder of perception and motor organisation. Developmental Medicine and Child Neurology, 12, 178-185.

David, R., Deuel, R., Ferry, P., Gascon, G., Golden, G. Rapin, I., Rosenberger, P. & Shaywitz, B. (1981). Proposed nosology of disorders of higher cerebral function in children. Minneapolis, MN: Child Neurology Society.

De Ajuriguerra, J. & Stambak, M. (1969). Developmental dyspraxia and psychomotor disorders. In P.J. Vinken & G. Bruyn (Eds.), Handbook of clinical neurology: Vol.4. Disorders of speech, perception and symbolic behaviour. Amsterdam: North Holland.

DeGangi, B., Berk, R. & Valvano, J. (1983). Assessment of motor and neurological function in high risk infants. Journal of Behavioural Pediatrics, 4, 182-187.

Denckla, M.B. (1984). Developmental dyspraxia: The clumsy child. In M.D. Levene & P. Satz, Middle childhood: Development and dysfunction. University Park Press.

Denckla, M.B. & Roeltgen, D.P. (1992). Disorders of motor function and control. In I. Rapin & S.J. Segalowitz (Eds.), Handbook of neuropsychology, Vol. 6: Child neuropsychology. Amsterdam: Elsevier Science Publishers B.V.

Deuel, R.K. (1992). Motor skill disorders. In S.R. Hooper, G.W. Hynd and R.E. Mattison, Developmental disorders: Diagnostic criteria and clinical assessment. London: Lawrence Erlbaum.

De Vries, L.S. (1987). Ischaemic lesions in the premature infant: correlation of imaging and outcome. Doctoral thesis, University of Utrecht, The Netherlands.

De Vries, L.S., Dubowitz, L.M.S., Dubowitz, V., Kaiser, A., Lary, S. Silverman, M., Whitelaw, A. & Wigglesworth, J.S. (1985). Predictive value of cranial ultrasound: a reappraisal. Lancet, ii, 137–140.

De Vries, L.S., Dubowitz, L.M.S., Dubowitz, V. & Pennock, J.M. (1990). Brain disorders in the newborn. London: Wolfe Medical Publications Ltd.

De Vries, L.S., Regev, R., Wigglesworth, J.S. & Dubowitz, L.M.S. (1988). Ultrasound evolution and later outcome of infants with periventricular densities. Early Human Development, 16, 225–233.

Dewey, D. & Kaplan, B. (1992). Subtyping of developmental motor deficits. Journal of Clinical and Experimental Neuropsychology, 14, 50.

Drillien, C.M. (1961). The incidence of mental and physical handicaps in school-age children of very low birthweight. Pediatrics, March, 452–464.

Drillien, C.M. (1967). The incidence of mental and physical handicap in school-age children of very low birthweight: II. Pediatrics, 39, 238–247.

Drllien C.M. & Drummond, M. (1983). Development screening and the child with special needs: A population study of 5000 children. Clinics in Developmental Medicine, No. 86. London: S.I.M.P. with heinemann Medical.

Drillien, C.M., Thomson, A.J.M. & Burgoyne, K. (1980). Low-birthweight children at early school-age: A longitudinal study. Developmental Medicine and Child Neurology, 22, 26–47.

DSM III-R (1987). Diagnostic and Statistical Manual of Mental Disorders (3rd Edition-Revision). Washington DC: American Psychiatric Association.

Dubowitz, L.M.S., Levene, M.I., Morante, A., Palmer, P. & Dubowitz, V. (1981). Neurological signs in newborns with intraventricular haemorrhage: a correlation with real time ultrasound. Journal of Pediatrics, 99, 127–133.

Dunn, H.G. (Ed.). (1986). Sequelae of low birthweight: The Vancouver Study. Clinics in Developmental Medicine, No. 95/96. London: MacKeith Press.

Dunn, L. & Dunn, L. (1981). The Peabody Picture Vocabulary Test-Revised. Circle Pines, Minnesota: American Guidance Service.

Eilers, B.L., Desai, N.S., Wilson, M.A. & Cunningham, M.D. (1986). Classroom performance and social factors of children with birthweights of 1250 grams or less. Follow-up at 5-8 years of age. Pediatrics, 77, 203-208.

Elliott, C.D., Murray, D.J. & Pearson, L.S. (1983). The British Ability Scales. NFER-Nelson Publishing Co. Ltd.

Evans, P. & Alberman, E. (1985). Recording motor defects of children with cerebral palsy. Developmental Medicine and Child Neurology, 27, 404-406.

Evans, P., Johnson, A., Mutch, L. & Alberman, E. (1986). Report of a meeting on the standardisation of the recording and reporting of cerebral palsy. Developmental Medicine and Child Neurology, 28, 547-548.

Evans, P., Johnson, A., Mutch, L. & Alberman, E. (1989). A standard form for recording clinical findings in children with a motor deficit of central origin. Developmental Medicine and Child Neurology, 31, 119-127.

Evrard, P., Miladi, N., Bonnier, C. & Gressens, P. (1992). Normal and abnormal development of the brain. In I. Rapin & S.J. Segalowitz (Eds.), Handbook of neuropsychology, Vol; 6, Child neuropsychology. Amsterdam: Elseviers Science Publishers.

Fawer, C-L., & Calame, A. (1991). Significance of ultrasound appearances in the neurological development and cognitive abilities of preterm infants at 5 years. European Journal of Pediatrics, 150, 515-520.

Fawer, C-L., Calame, A., Perentes, E. & Anderegg, A. (1985). Periventricular leukomalacia: a correlation study between real-time ultrasound and autopsy findings. Neuroradiology, 27, 292-300.

Flynn, J.R. (1984). The mean IQ of Americans: Massive gains 1932 to 1978. Psychological Bulletin, 95, 29-51.

Fog, E. & Fog, M. (1963). Cerebral inhibition examined by associated movements. In Bax, M. and MacKeith, R. (Eds.), Minimal cerebral dysfunction, Little Club Clinics in Developmental Medicine, No. 10. London: National Spastics Society.

Ford, L.M., Steichen, J., Steichen-Ash, P.A., Babcock, D. & Fogelson, M.H. (1989). Neurological status and intracranial hemorrhage in very-low-birthweight preterm infants: Outcome at 1 year and 5 years, American Journal of Disease in Children, 143, 1186-1190.

Forsstrom, A. & Von Hofsten, C. (1982). Visually directed reaching of children with motor impairments. Developmental Medicine and Child Neurology, 24, 653-661.

Francis-Williams, J. & Davies, P.A. (1974). Very low birthweight and later intelligence. Developmental Medicine and Child Neurology, 16, 709-728.

Frankenburg, W.K., Dodds, J.B. & Fandal, A.W. (1973). Denver Developmental Screening Test: Manual/workbook for nursing and paramedical personnel. Colorado: University of Colorado Medical Center.

Frostig, M., Welty Lefever, D. & Whittesley, J.R.B. (1961). A developmental test of visual perception for evaluating normal and neurologically handicapped children, Perceptual and Motor Skills, 12, 383-394.

Fuggle, P.W., Tokar, S., Grant, D.B. & Smith, I. (1992). Rising IQ scores in British children. Journal of Child Psychology and Psychiatry, 33, 1241-1247.

Geuze, R.H. & Kalverboer, A.F. (1987). Inconsistency and adaptation in timing of clumsy children. Journal of Human Movement Studies, 13, 421-432.

Gibson, J.J. (1966). The senses considered as perceptual systems. Boston: Houghton Mifflin.

Goldenberg, R.L., Nelson, K.G., Koski, J.F. & Cutter, G.R. (1985). Low birthweight, intrauterine growth retardation and preterm delivery. American Journal of Obstetrics and Gynecology, 152, 980-984.

Goodenough, F.L., Maurer, K.M. & Van Wagenen, M.J. (1940). Minnesota Preschool Scale. Minnesota: American Guidance Service.

Goodman, R. (1991). Developmental disorders and structural brain development. In M. Rutter and P. Casaer (Eds.), Biological risk factors for psychosocial disorders. Cambridge: Cambridge University Press.

Gordon, N. & McKinlay, I.A. (1980). Introduction. In N. Gordon and I.A. McKinlay (Eds.), Helping clumsy children. Edinburgh: Churchill Livingstone.

Graham, M., Levene, M.T., Trounce, J.Q. & Rutter, N. (1987). Prediction of cerebral palsy in very low birthweight infants: prospective ultrasound study, Lancet, ii, 593-596.

Greer, K. (1984). Physiology of motor control. In M.M. Smyth and A.M. Wing (Eds.), The psychology of human movement. London: Academic Press.

Greisen, G. (1992). Ischaemia of the preterm brain. Biology of the Neonate, 62, 243-247.

Griffiths, R. (1967). Griffiths Mental Development Scales for testing babies and young children from birth to eight years of age. Amersham: Association of Research in Infant Development.

Gubbay, S.S. (1975). The clumsy child: A study of developmental apraxia and agnosic ataxia. London: W.B. Saunders Co. Ltd.

Gubbay, S.S. (1978). The management of developmental dyspraxia. Developmental Medicine and Child Neurology, 20, 643–646.

Gubbay, S.S., Ellis, E., Walton, J.N. & Court, S.D.M. (1965). Clumsy children: A study of apraxic and agnosic defects in 21 children. Brain, 88, 295–312.

Hack, M., Fanaroff, A.A. & Merkatz, I.R. (1979). The low birthweight infant: Evolution and changing outlook. New England Journal of Medicine, 301, 1162–1165.

Hadders–Algra, M. (1987). Correlates of brain dysfunction in children – a follow up study. Doctoral Thesis. University of Groningen, The Netherlands.

Hadders–Algra, M., Huisjes, H.J. & Touwen, B.C.L. (1988). Preterm or small for gestational age infants: neurological and behavioural development at the age of 6 years. European Journal of Pediatrics, 147, 460–467.

Hadders–Algra, M., Touwen, B.C.L. & Huisjes, H.J. (1986). Neurologically deviant newborns: Neurological and behavioural development at the age of six years. Developmental Medicine and Child Neurology, 28, 569–578.

Hagberg, B. & Hagberg, G. (1993). The origins of cerebral palsy. In T.J. David (Ed.), Recent advances in paediatrics, XI. Edinburg, London: Churchill Livingstone.

Harris, D.B. (1963). Goodenough–Harris Drawing Test (Manual). New York: Harcourt Brace Jovanovich.

Harter, S. (1986). Processes underlying the construction, maintenance, and enhancement of the self–concept in children. In I. Suls and A.G. Greenwald (Eds.), Psychological perspectives on the self. London: Lawrence Elbaum Associates.

Harter, S. & Pike, R. (1983). The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children. Denver: University of Denver Press.

Harter, S. & Pike, R. (1984). The Pictorial Scale of Perceived Competence and Social Acceptance for young children. Child Development, 55, 1969–1982.

Haskell, S.H. (1972). Visuoperceptual, visuomotor, and scholastic skills of alternating and uniocular squinting children. The Journal of Special Education, 6, 3–8.

Hawgood, S., Spong, J. & Yu, V.Y.H. (1984). Intraventricular haemorrhage: incidence and outcome in a population of very low birthweight infants. American Journal of Diseases in Childhood, 138, 136–139.

Henderson, S.E., Barnett, A. & Henderson, L. Visuospatial difficulties and clumsiness: on the interpretation of conjoined deficits. In preparation.

Henderson, S.E. & Hall, D.(1982). Concomitants of clumsiness in young school children. Developmental Medicine and Child Neurology, 24, 448–460.

Henderson, S.E. & Sugden, D.A. (1992). Movement Assessment Battery for Children (Manual). Sidcup: The Psychological Corporation.

Hertzig, M.E. (1981). Neurological 'soft' signs in low birthweight children. Developmental Medicine and Child Neurology, 23, 778–791.

Hirsch, E. & Niedermeyer, F.C. (1973). The effects of tracing prompts and discrimination training on kindergarten handwriting performance. The Journal of Educational Research, 67, 81–86.

Hoare, D.G. (1991). Classification of movement dysfunctions in children: Descriptive and statistical approaches. Doctoral thesis, University of Western Australia, Australia.

Hoare, D.G. & Larkin, D. (1991). Kinaesthetic abilities of clumsy children. Developmental Medicine and Child Neurology, 33, 671–678.

Hulme, C., Smart, A. & Moran, G. (1982). Visual perceptual deficits in clumsy children. Neuropsychologia, 20, 475–481.

Hulme, C., Smart A., Moran, G. & McKinlay, I.A. (1984). Visual, kinaesthetic and cross modal judgements of length by clumsy children: A comparison with young normal children. Child: Care, Health and Development, 10, 117–125.

Hunt, J.V., Tooley, W.H. & Harvin, D. (1982). Learning disabilities in children with birthweights less than or equal to 1500 grams. Seminars in Perinatology, 6, 280–287.

ICD–9–CM (1989). International Classification of Diseases–9–Clinical Modifications. U.S. Department of Health and Human Services: DHHS Publication No. (PHS, 89–1260).

Illsley, R. & Mitchell, R.G. (1984). Low birthweight: a medical psychological and social study. Chichester; John Wiley.

Ingram, T.T.S. (1964). Paediatric aspects of cerebral palsy. Edinburgh: Livingstone.

Jensen, T.S., Boggild–Andersen, B., Schmidt, J., Ankerhus, J. & Hansen, E. (1988). Perinatal risk factors and first year vocalizations: Influence on preschool language and motor performance, Developmental Medicine and Child Neurology, 30, 153–161.

Johnston, O., Short, H. & Crawford, J. (1987). Poorly coordinated children: A survey of 95 cases. Child: Care, Health and Development, 13, 361–376.

Kakebeeke, T.H., Jongmans, M.J., Dubowitz, L.M.S., Schoemaker, M. & Henderson, S.E. (1993). Some aspects of the reliability of Touwen's Examination of the Child with Minor Neurological Dysfunction. Developmental Medicine and Child Neurology, 35, 1097–1105.

Kalverboer, A.I. & Brouwer, W.H. (1983). Visuo–motor behaviour in pre–school children in relation to sex and neurological status. An experimental study on the effect of 'time–pressure'. Journal of Child Psychology and Psychiatry, 24, 65–68.

Keogh, J.K. & Sugden, D.A. (1985). Movement skill development. New York: Macmillan Publishing Company.

Keogh, J.F., Sugden, D.A., Reynard, C.L. & Calkins, J.A. (1979). Identification of clumsy children: Comparisons and comments. Journal of Human Movement Studies, 5, 32–41.

Klein, N., Hack, M., Gallagher, J. & Fanaroff, A.A. (1985). Preschool performance of children with normal intelligence who were very low–birth–weight infants. Pediatrics, 75, 531–537.

Klein, N.K., Hack, M.& Breslan, H. (1989). Children who were very low birthweight: development and achievement at 9 years of age. Journal of Developmental and Behavioural Pediatrics, 10, 32–37.

Kolb, B. (1993). Brain development, plasticity and behaviour. In M.H. Johnson (Ed.), Brain development and cognition. Oxford: Blackwell.

Kopp, C.B. & Krakow, J.B. (1983). The developmentalist and the study of biological risk: A view of the past with an eye towards the future. Child Development, 54, 1086–1108.

Krisnamoorthy, K.S., Kuehnle, K., Todres, I. & Delong, G. (1984). Neurodevelopmental outcome of survivors with past hemorrhagic hydrocephalus following grade II intraventricular hemorrhage. Annals of Neurology, 15, 201–204.

Krus, P.H., Bruininks, R.H. & Roberston, G. (1981). Structure of motor abilities in children. Perceptual and Motor Skills, 52, 119–129.

Largo, R.H., Pfister, D., Molinari, L., Kundu, S., Lipp, A. & Duc, G. (1989). Significance of prenatal, perinatal and postnatal factors in the development of AGA preterm infants at five to seven years. Developmental Medicine and Child Neurology, 31, 440–456.

Largo, R.H., Molinari, L., Kundu, S., Hunziker, U. & Duc, G. (1990a). Neurological outcome in high risk weight appropriate for gestational age preterm children at early schoolage. European Journal of Pediatrics, 149, 835–844.

Largo, R.H., Molinari, L., Kundu, S., Lipp, A. & Duc, G. (1990b). Intellectual outcome, speech and school performance in high risk preterm children with birthweight appropriate for gestational age. European Journal of Pediatrics, 149, 845–850.

Laszlo, J.I. & Bairstow, P.J. (1980). The measurement of kinaesthetic sensitivity in children and adults. Developmental Medicine and Child Neurology, 22, 454–464.

Laszlo, J.I. & Bairstow, P.J. (1985). Perceptual–motor behaviour: Developmental assessment and therapy. New York: Praeger Publishers.

Laszlo, J.I., Bairstow, P.J., Bartrip, J. & Rolfe, U.T. (1988). Clumsiness or perceptuo–motor dysfunction ? In: A.M. Colley & J.R. Beech (Eds.), Cognition and action in skilled behaviour. Amsterdam: Elsevier Publishers B.V.

Lee, D.N. (1978). The functions of vision. In H.L. Pick & E. Saltzman (Eds.), Modes of perceiving and processing information. Hillsdale, N.J.: Erlbaum.

Lee, D.N. & Aronson, E. (1974). Visual proprioceptive control of standing in human infants. Perception and Psychophysics, 15, 529–532.

Lefebvre, F., Bard, H., Veilleux, A. & Martel, C. (1988). Outcome at school age of children with birthweights of 1000 grams or less. Developmental Medicine and Child Neurology, 30, 170–180.

Leonard, C.H., Clyman, R.I., Piecuch, R.E., Juster, R.P., Ballard, R.A. & Behle, M.B. (1990). Effect of medical and social risk factors on outcome of prematurity and very low birth weight. Journal of Pediatrics, 116, 620–626.

Levene, M., Dowling, S., Graham, M., Fogelman, K., Galton, M. & Philips, M. (1992). Impaired motor function (clumsiness) in 5 year old children: correlation with neonatal ultrasound scans, Archives of Disease in Childhood, 67, 687–690.

Levene, M.I., Fawer, C.L. & Lamont, R.F. (1982). Risk factors in the development of intraventricular haemorrhage in the preterm neonate. Archives of Disease in Childhood, 57, 410–417.

Levene, M.I., Wigglesworth, J.S & Dubowitz, V. (1983). Haemorrhagic periventricular leukomalacia in the neonate: a real–time ultrasound study. Journal of Pediatrics, 71, 794–797.

Leviton, A. & Paneth, N. (1990). White matter damage in preterm newborns an epidemiologic perspective. Early Human Development, 24, 1–22.

Levitt, S. (1982). Treatment of cerebral palsy and motor delay (2nd edition). Oxford: Blackwell.

Lipscomb, A.P., Thorburn, R.J., Reynolds, E.O.R., Stewart, A.L., Blackwell, R.J., Cusick, G. & Whitehead, M.D. (1981). Pneumothorax and cerebral haemorrhages in preterm infants. Lancet, i, 414–416.

Lis, C. (1969). Visuo–motor development and its disturbances in a sample of prematures born with birthweight below 1250 grams. Australian Journal on the Education of Backward Children, 16, 73–84.

Lloyd, B.W., Wheldall, K. & Perks, D. (1988). Controlled study of intelligence and school performance of very low birthweight children from a defined geographical area. Developmental Medicine and Child Neurology, 30, 36–42.

Lord, R. & Hulme, C. (1988). Visual perception and drawing ability in clumsy and normal children. British Journal of Developmental Psychology, 6, 1–9.

Losse, A., Henderson, S.E., Elliman, D., Hall, D., Knight, E. & Jongmans, M. (1991). Clumsiness in children – do they grow out of it ? A 10–year follow–up study. Developmental Medicine and Child Neurology, 33, 55–68.

Lowe, J. & Papile, L.A. (1990). Neurodevelopmental performance of very low–birth–weight infants with mild periventricular, intraventricular hemorrhage: Outcome at 5 to 6 years of age. American Journal of Diseases in Childhood, 144, 1242–1245.

Lundy–Ekman, L., Ivry, R., Keele, S. & Woollacott, M. (1991). Timing and force control deficits in clumsy children. Journal of Cognitive Neuroscience, 3, 367–376.

Lunsing, R.J., Hadders–Algra, M., Huisjes, H.J. & Touwen, B.C.L. (1992). Minor neurological dysfunction from birth to 12 years. I: Increase during late school–age. Developmental Medicine and Child Neurology, 34, 399–403.

Lyon, G. & Gadisseux, J–F. (1991). Structural abnormalities of the brain in developmental disorders. In M. Rutter & P. Casaer (Eds.), Biological risk factors for psychosocial disorders. Cambridge: Cambridge University Press.

Machin, G.A. (1975). A perinatal mortality survey in south east London, 1970–73: the pathological findings in 726 necropsies. Journal of Clinical Pathology, 28, 428–434.

Maeland, A.F. (1992). Identification of children with motor coordination problems. Adapted Physical Activity Quarterly, 9, 330–342.

Marlow, N., Ellis, A.M., Roberts, B.L. & Cooke, R.W.I. (1990). Five year outcome of preterm sextuplets related to size at birth. Archives of Disease in Childhood, 65, 543–456.

Marlow, N., Roberts, L. & Cooke, R.W.I. (1989). Motor skills in extremely low birthweight children at the age of 6 years. Archives of Disease in Childhood, 64, 839–847.

McCarthy, D. (1972). Manual for the Mccarthy Scales of Children's Abilities. New York: The Psychological Corporation.

McCormick, M.C., Brooks-Gunn, J., Workman-Daniels, K., Turner, J. & Peckham, G.J. (1992). The health and developmental status of very low birthweight children at school age. Journal of the American Medical Association, 267, 2204-2208.

McDonald, M.A., Sigman, M., & Ungerer, J.A. (1989). Intelligence and behaviour problems in 5-year-olds in relation to representational abilities in the second year of life. Journal of Developmental and Behavioural Paediatrics, 10, 86-91.

Michelsson, K. & Lindahl, E. (1993). Relationship between perinatal risk factors and motor development at the ages of 5 and 9 years. In A.F. Kalverboer, B. Hopkins & R. Geuze (Eds.), Motor development in early and later childhood: longitudinal approaches. Cambridge: Cambridge University Press.

Miller, N. (1986). Dyspraxia and its management. London: Croom Helm.

Miller, L.J. (1988). Miller Assessment for Preschoolers. Sidcup: The Psychological Corporation.

Murton, L.J., Butt, W.W., Mackay, R.J., Roy, R.N.D. & De Crespigny, L.Ch. (1985). Perinatal factors, periventricular haemorrhage and mortality in very low birthweight infants. Australian Paediatric Journal, 21, 39-43.

Nashner, L.M., Shumway-Cook A. & Marin, O. (1983). Stance posture control in select groups of children with cerebral palsy: Deficits in sensory organisation and muscular coordination. Experimental Brain Research, 49, 393-409.

Neligan, G.A., Kolvin, J., Scott, D.M. & Gardide, R.F. (1976). Born too small or born too soon, a follow-up study to seven years of age. Clinics in Developmental Medicine, No. 61. Spastics International.

Nickel, R.E., Bennett, F.C. & Lamson, F.N. (1982). School performance of children with birthweights of 1000 g or less. American Journal of Diseases in Children, 136, 105-110.

Noble-Jamieson, C.M., Lukeman, D., Silverman, M. & Davies, P.A. (1982). Low birth weight children at school age: Neurological, psychological and pulmonary function. Seminars in Perinatology, 6, 266-273.

O'Connor, N. & Hermelin, B. (1987). Visual and graphic abilities of the idiot savant artist. Psychological Medicine, 17, 79-90.

Ornstein, M., Ohlsson, A., Edmonds, J. & Asztalos, E. (1991). Neonatal follow-up of very low birthweight/extremely low birthweight to school age: a critical review. Acta Paediatrica Scandinavia, 80, 741-748.

Orton, S.T. (1937). Reading, writing and speech problems in children. New York: Norton.

O'Shea, T.M., Volberg, F. & Dillard, R.G. (1993). Reliability of interpretation of cranial ultrasound examinations of very low birthweight neonates, Developmental Medicine and Child Neurology, 35, 97–101.

Pape, K.E. (1989). Etiology and pathogenesis of intraventricular hemorrhage in newborns. Journal of Pediatrics, 84, 382–384.

Pape, K.E., Blackwell, R.J., Cusick, G., Sherwood, A., Houang, M.T., Thorburn, R. & Reynolds, E.O.R. (1979). Ultrasound detection of brain damage in preterm infants. Lancet, i, 1261–1264.

Pape, K.E., Buncic, R.J., Ashby, S. & Fitzhardinghe, P.M. (1978). The status at two years of low birthweight infants born in 1974 with birthweights less than 1001 gm. Journal of Pediatrics, 92, 253–260.

Pape, K.E. & Wigglesworth, J.S. (1979). Haemorrhage, ischaemia and the perinatal brain. Clinics in Developmental Medicine, No. 69/70. London: S.M.I.P., Heinemann.

Papile, L.A., Burstein, J., Burstein, R. & Koffler, H. (1978). Incidence and evolution of subependymal and intraventricular haemorrhage. Journal of Pediatrics, 92, 529–534.

Partridge, C., Han, B., Babock, D. & Steichen, J. (1983). Optimal timing for diagnostic cranial ultrasound in low birthweight infants: detection of intracranial hemorrhage and ventricular dilatation, Journal of Pediatrics, 102, 281–287.

Perlman, J.M & Volpe, J.J. (1986). Intraventricular hemorrhage in extremely small premature infants. American Journal of Diseases in Children, 140, 1122–1124.

Petrauskas, R.J. & Rourke, B.P. (1979). Identification of subtypes of retarded readers: A neuropsychological, multivariate approach. Journal of Clinical Neuropsychology, 1, 17–37.

Pinto, J., Paneth, N., Kazam, E., Kairam, R., Wallenstein, S., Rose, W., Rosenfeld, D., Schofeld, S., Stein, I. & Witomski, T. (1988). Interobserver variability in neonatal cranial ultrasonography. Paediatric and Perinatal Epidemiology, 2, 43–58.

Portnoy, S., Callias, M., Wolke, D. & Gamsu, H. (1988). Five-year follow-up study of extremely low-birthweight infants. Developmental Medicine and Child Neurology, 30, 590–598.

Puterman, M.L. & Dunn, H.G. (1986). Statistical analysis of mild brain dysfunctions. In H. Dunn (Ed.), Sequelae of low birthweight: The Vancouver study. Oxford: Mac Keith Press.

Rarick, G.L., Dobbins, D.A. & Broadhead, G.D. (1976). The motor domain and its correlates in educationally handicapped children. Englewood Cliffs, N.J.: Prentice Hall.

Richman, N, Stevenson, J. & Graham, P.J. (1982). The Behaviour Check List. Pre-school to school: A behavioural study. London: Academic Press.

Rickards, A.L., Ford, G.W., Kitchen. W.H., Doyle, L.W., Lissenden, J.V. & Keith, C.G. (1987). Extremely low birthweight infants: neurological, psychological growth and health status beyond 5 years of age. Medical Journal of Australia, 147, 476-481.

Robertson, C.M.T., Etches, P.C. & Kyle, J.M. (1990). Eight year school performance and growth of preterm, small for gestational age infants: A comparative study with subjects matched for birthweight or for gestational age. The Journal of Pediatrics, 116, 19-26.

Ross, G., Lipper, E.G. & Auld, P.A.M. (1990). Social competence and behavior problems in premature children at school age. Pediatrics, 86, 391-397.

Ross, G., Tesman, J., Auld, P.A.M., & Nass, R. (1992). Effects of subependymal and mild intraventricular lesions on visual attention and memory in premature infants, Developmental Psychology, 28, 1067-1074.

Rourke, B.P., Bakker, D.J., Fisk, J.L. & Strang, J.D. (1983). Child neuropsychology: An introduction to theory, research, and clinical practice. London: The Guilford Press.

Rushton, D.I., Preston, P.R. & Durbin, G.M. (1985). Structure and evolution of echodense lesions in the neonatal brain. Archives of Disease in Childhood, 60, 798-808.

Rutter, M. (1965). Classification and categorization in child psychiatry. Journal of Child Psychology and Psychiatry, 6, 71-83.

Rutter, M. (1967). A children's behaviour questionnaire for completion by teachers: preliminary findings. Journal of Child Psychology and Psychiatry, 8, 1-11.

Saigal, S., Szatmari, P., Rosenbaum, P., Campbell, D. & King, S. (1990). Intellectual and functional status at school entry of children who weighed 1000 g or less at birth: A regional perspective of births in the 1980s. Journal of Pediatrics, 116, 409-416.

Samaroff, A.J. & Chandler, M.J. (1975). Reproductive risk and the continuum of caretaking casualty. In F.D. Horowitz (Ed.), Review of child development research, Vol. IV. Chicago: University of Chigaco Press.

Schmidt, R.A. (1982). Motor control and learning: a behavioral emphasis. Champaign (Illinois): Human Kinetics.

Schoemaker, M.M. (1992). Physiotherapy for clumsy children: An effect evaluation study. Doctoral thesis, University of Groningen, The Netherlands.

Schoemaker, M., Jongmans, M.J., Kakebeeke, T.H. & Henderson, S.E. Some aspects of the validity of Touwen's Examination of the Child with Minor Neurological Dysfunction. *Submitted*.

Scymonowicz, W., Yu, V.Y.H., Bajuk, B. & Astbury, J. (1986). Neurodevelopmental outcome of periventricular haemorrhage and leukomalacia in infants 1250 g or less at birth. Early Human Development, 14, 1-7.

Sell, E.J. (1986). Outcome of very low birthweight infants. In The Tiny Baby. Clinics in Perinatology, 13, 451-459.

Shafer, S.Q., Shaffer, D., O'Connor, P.A. & Stokman, C.J. (1983). Hard thoughts on 'soft signs'. In M. Rutter (Ed.), Developmental neuropsychiatry. Edinburgh: Churchill Livingstone.

Shepard, R.N. & Farrell, J.E. (1985). Representation of the orientations of shapes. Acta Psychologica, 59, 103-121.

Shepard, R.N. & Metzler, J. (1971). Mental rotation of three-dimensional objects. Science, 171, 701-703.

Shumway-Cook, A. & Woollacott, M.H. (1985). The growth of stability: Postural control from a developmental perspective. Journal of Motor Behavior, 17, 131-147.

Siegel, L.S. (1982). Reproductive, perinatal and environmental variables as predictors of development of preterm (< 1501 grams) and fullterm children at 5 years. Seminars in Perinatology, 6, 274-279.

Siegel, S. & Castellan, N. (1988). Nonparametric statistics for the behavioral sciences. New York: McGraw Hill Book Company.

Sinha, S.H., Davies, J.M., Sims, D.G. & Chiswick, M.L. (1985). Relation between periventricular haemorrhage and ischaemic brain lesions diagnosed by ultrasound in very preterm infants. Lancet, ii, 1154-1156.

Smith, L. Smorvik, D., Summer, F.F. & Von Tetzchner, S. (1982). A longitudinal study of low birthweight children: reproductive, perinatal and environmental precursors of developmental status at 3 years of age. Seminars in Perinatology, 6, 294-304.

Smyth, M.M. & Wing, A.M. (1984). Movement, action and skill. In M.M. Smyth and A.M. Wing (Eds.), The psychology of human movement. London: Academic Press.

Somerville, S.C. & Bryant, P.E. (1985). Young children's use of spatial coordinates. Child Development, 56, 604-613.

Sonksen-Silver Acuity System (1988). Instruction manual. Windsor: Keeler Ltd.

Sostek, A.M. (in press). Prematurity as well as intraventricular haemorrhage influence developmental outcome at five years. In S.L. Friedman & M. Sigman (Eds.), Psychological development of preterm infants. Norwood, N.J.: Ablex.

Sostek, A.M., Smith, Y.F., Katz, K.S. & Grant, E.C. (1987). Developmental outcome of preterm infants with intraventricular hemorrhage at one and two years of age. Child Development, 37, 779–786.

Spreen, O., Tupper, D., Risser, A., Tuokko, H. & Edgell, D. (1984). Human developmental neuropsychology. Oxford: Oxford University Press.

Stanley, F.J. & English, D.R. (1986). Prevalence of risk factors for cerebral palsy in a total population cohort of low birthweight (< 2000 g) infants. Developmental Medicine and Child Neurology, 28, 559–568.

Steel, K.O., Glover, J.E. & Spasoff, R.A. (1991). The Motor Control Assessment: An instrument to measure motor control in physically disabled children. Archives of Physical and Medical Rehabilitation, 72, 549–553.

Stephenson, E., McKay, C. & Chesson, R. (1991). The identification and treatment of motor/learning difficulties: parents' perceptions and the role of the therapist. Child: Care, Health and Development, 17, 91–113.

Stereo Tests (1988). Chicago: Stereo Optical Company, Inc.

Stewart, A.L., Costello, A.M. de L., Hamilton, P.A., Baudin, J., Townsend, J., Bradford, B.C. & Reynolds, E.O.R. (1989). Relationship between neurodevelopmental status of very preterm infants at one and four years. Developmental Medicine and Child Neurology, 31, 756–765.

Stewart, A.L., Reynolds, E.O.R. & Lipscomb, A.P. (1981). Outcomes for infants of very low birthweight: Survey of the world literature. Lancet, i, 1038–1041.

Stewart, A.L., Reynolds, E.O.N., Hope, P.L. et al. (1987). Probability of neurodevelopmental disorders estimated from ultrasound appearance of brains of very preterm infants. Developmental Medicine and Child Neurology, 29, 3–11.

Stewart, A.L., Thorburn, R.J., Hope, P.L., Goldsmith, M., Lipscomb, A.P. & Reynolds, E.O.R. (1983). Ultrasound appearance of the brain in very preterm infants and neurodevelopmental outcome at 18 months of age. Archives of Disease in Childhood, 58, 598–604.

Stokman, C.J., Shafer, S.Q., Shaffer, D., Ng, SK-C., O'Conner, P.A. & Wolff, R.R. (1986). Assessment of neurological "soft signs" in adolescents: reliability studies. Developmental Medicine and Child Neurology, 28, 428–439.

Stott, D.H. (1963). The social adjustment of children. Manual to the Bristol Social Adjustment Guides. London: University of London Press.

Stott, D.H., Moyes, F.A. & Henderson, S.E. (1984). Test of Motor Impairment–Henderson Revision. Guelph, Ontario: Brook Educational Publishing Ltd.

Stutsman, R. (1931). Guide for administering the Merrill–Palmer Scale of Mental Tests. New York: World Book Company.

Sugden, D.A. & Keogh, J.F. (1990). Problems in movement skill development. Columbia: University of South Carolina Press.

Sugden, D.A. & Sugden, L. (1990). The assessment and management of movement skill problems. Leeds: School of Education.

Sugden, D.A. & Wann, C. (1987). The assessment of motor impairment in children with moderate learning difficulties. British Journal of Educational Psychology, 57, 225–236.

Tabachnick, B.G. & Fidell, L.S. (1989). Using multivariate statistics (2nd Edition). New York: Harper Collins.

Taub, H.B., Goldstein, K.M. & Caputo, D.V. (1977). Indices of neonatal prematurity as discriminators of development in middle childhood. Child Development, 48, 797–805.

Taylor, D.C. (1981). The influence of sexual differentiation on growth, development and disease. In J.A. Davis & J. Dobbing (Eds.), Scientific foundations of pediatrics, 2nd Edition. London: Heinemann Medical.

Taylor, H.G. (1987). The meaning and value of soft signs in behavioral sciences. In D.E. Tupper (Ed.), Soft neurological signs. New York: Grune and Stratton.

Tekolste, K.A., Bennet, F.C. & Mack, L.A. (1985). Follow–up of infants receiving cranial ultrasound for intracranial hemorrhage. American Journal of Diseases of Children, 139, 299–303.

The Scottish Low Birthweight Study Group (1992). The Scottish low birthweight study: I. Survival, growth, neuromotor and sensory impairment. Archives of Disease in Childhood, 67, 675–681.

Thorburn, R.J., Lipscomb, A.P., Stewart, A.L., Reynolds, E.O.R. & Hope, P.L. (1982). Timing and antecedents of periventricular haemorrhage and of cerebral atrophy in very preterm infants. Early Human Development, 7, 221–238.

Tizard, B., Blatchford, P. & Burke, J. (1988). Young children in the inner city. London: Lawrence Erlbaum.

Touwen, B.C.L. (1979). The Examination of the Child with Minor Neurological Dysfunction. Second Edition. Clinics in Developmental Medicine, No. 71. London: S.I.M.P. with Heinemann Medical.

Touwen, B.C.L. (1980). The preterm infant in the extrauterine environment: Implications for neurology. Early Human Development, 4, 287–300.

Touwen, B.C.L. (1986). Very low birthweight infants. European Journal of Pediatrics, 145, 460.

Trounce, J.Q., Fagau, D. & Levene, M.I. (1986). Intraventricular haemorrhage and periventricular leucomalacia: ultrasound and autopsy correlation. Archives of Disease in Childhood, 62, 1203–1207.

Trounce, J.Q., Shaw, D.E., Levene, M.I. & Ruter, N. (1988). Clinical risk factors and periventricular leukomalacia. Archives of Disease in Childhood, 63, 17–23.

Van de Bor, M., Ens–Dokkum, M., Schreuder, A.M., Veen, S., Brand, R. & Verloove–Vanhorick, S.P. (1993). Outcome of periventricular–intraventricular haemorrhage at five years of age, Developmental Medicine and Child Neurology, 35, 33–41.

Van der Meulen, J.H.P., Denier van der Gon, J.J., Gielen, C.C.A.M., Gooskens, R.H.J.M. & Willemse, J. (1991). Visuomotor performance of normal and clumsy children. 1: Fast goal–directed arm–movements with and without visual feedback. Developmental Medicine and Child Neurology, 33, 40–54.

Vohr, B.R. & Garcia Coll, C.T. (1985). Neurodevelopmental and school performance of very low–birth–weight infants: A seven–year longitudinal study. Pediatrics, 76, 345–350.

Volpe, J.J. (1987). Neurology of the newborn (2nd Edition). London: W.B. Saunders Company.

Volpe, J.J. (1992). Brain injury in the premature infant – current concepts of pathogenesis and prevention. Biology of the Neonate, 62, 231–242.

Wall, A.E. (1982). Physically awkward children: A motor development perspective. In J.P. Das, R.F. Mulcahy & A.E. Wall (Eds.), Theory and research in learning disabilities. New York: Plenum Press.

Wall, A.E., McClements, J., Bouffard, M., Findlay, H. & Taylor, M.J. (1985). A knowledge–based approach to motor development: Implications for the physically awkward. Adapted Physical Activity Quarterly, 2, 21–42.

Walton, J.N., Ellis, E. & Court, S. (1962). Clumsy children: Developmental apraxia and agnosia. Brain, 85, 603–612.

Wechsler, D. (1974). Wechsler Intelligence Scale for Children–Revised Edition. New York: The Psychological Corporation.

Wechsler, D. (1967). Wechsler Preschool and Primary Scale of Intelligence. New York: The Psychological Corporation.

Weindling, A.M., Wilkinson, A.R., Cook, J., Calvert, S.A., Fok, T.F. & Rochefort, M.J. (1985). Perinatal events which precede periventricular haemorrhage and leukomalacia in the newborn. British Journal of Obstetrics and Gynaecology, 92, 1218–1223.

Wiener, G., Rider, R.V., Oppel, W.C. & Harper, P.A. (1968). Correlates of low birthweight: Psychological status at eight to ten years of age. Pediatric Research, 2, 110–118.

Williams, M.L., Lewandowski, L.J., Coplan, J. & D'Eugenio, D.B. (1987). Neurodevelopmental outcome of preschool children born preterm with and without intracranial hemorrhage. Developmental Medicine and Child Neurology, 29, 243–249.

Williams, H.G., Woollacott, M.H. & Ivry, R. (1992). Timing and motor control in clumsy children. Journal of Motor Behavior, 24, 165–172.

Williamson, W.D., Desmond, M.M., Wilson, G.S., Murphy, M.A., Rolelle, J. & Garcia-Prats, J.A. (1983). Survival of low birthweight infants with neonatal intraventricular haemorrhage. American Journal of Disease in Childhood, 137, 1181–1184.

Wolke, D. (1991). Annotation: Supporting the development of low birthweight infants. Journal of Child Psychology and Psychiatry, 32, 73–741.

Wright Rand, C. (1973). Copying in drawing: The importance of adequate visual analysis versus the ability to utilize drawing rules. Child Development, 44, 47–53.

Yloppo, A. (1919). Das Wachstum der Fruhgeborenen von der Geburt bis zum Schulalter. Zeitschrift fur Kinderheilkunde, 24, 111–178.

Yu, V.Y.H., Loke, H.L., Bajuk, B., Scymonowicz, W., Orgill, A.A. & Astbury, J. (1986). Prognosis for infants born at 23 to 28 weeks gestation. British Medical Journal, 293, 1200–1203.

APPENDIX A

Letter to parents

FOLLOW-UP STUDY OF PREMATURE CHILDREN
A collaborative project between the Hammersmith Hospital and the Institute of Education.

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Dear Mrs./Ms/Mr.....,

We would like to begin this letter by thanking you for your willingness to participate in our project. So that you know exactly what will be involved in this project we would like to give you some more information.

As we might have mentioned to you earlier, the aim of our project is to find out how children who were born prematurely are doing at school age. We are particularly interested to find out whether there is a difference between the children who were 'just premature' and those who were very ill. If we can identify any of those who might have problems earlier in the future and thus suggest appropriate treatment and advice, we hope to improve the care of our premature infants even further.

The assessment we intend to carry out will be similar to the one we did earlier in the follow-up clinic at the Hammersmith Hospital. In addition to this, we are interested in how the children approach ordinary school activities such as reading, drawing and making jigsaws. So that we can look carefully at each child during these tasks we would like to make a videotape of the children's activities. We estimate that it will take approximately 2 1/2 - 3 hours to do all the things we plan as the children might want to have a snack in the middle. We would also like to ask both you and your child's teacher to complete a questionnaire relating to how your child behaves at home and at school. Our findings will naturally remain completely confidential and will not be communicated to anyone without your consent.

As the amount of space available to us at the Hospital is too small, we intend to carry out the tests at the Institute of Education where two of the workers on this project are based. The Institute is situated in Central London not far from King's Cross/Euston station (map enclosed). The room we are meeting is room 788 on the 7th floor of the main building. We will be happy to compensate you for any expenses incurred in this trip. If you are coming up by car could you let us know as soon as possible please so we can arrange a parking space.

We look forward to see you and your child on .....

Yours sincerely,

Dr. L. Dubowitz
Dr. S.E. Henderson
Marian Jongmans

APPENDIX B

Individual data for the 12 children who were consistently slow on the form boards

Table B.1: Individual data on verbal and constructional ability for the 12 consistently slow children on the form boards.

Ss	VA	Griffiths form board		MASH form board		MASH form board conditions						Block design			Graphic skills				
						normal		rotated		turned		II	III	V	VMI	Draw-a-man			
		T	E	T	E	T	E	T	E	T	E	T			score	mot	pro	dep	det
1	42	89	1	160	3	12	1	15	1	90	4	41	20	31	10	0.29	0.56	0.44	0.21
2	42	68	4	127	4	32	3	32	2	111	2	34	60	78	5	0.00	0.00	0.28	0.09
3	44	62	0	119	4	15	0	28	0	100	1	23	40	41	6	0.00	0.11	0.50	0.09
4	44	45	1	103	5	11	0	68	5	103	2	14	60	19	9	0.14	0.56	0.28	0.33
5	46	70	1	89	5	14	0	27	2	66	1	41	52	22	7	0.29	0.56	0.72	0.30
6	50	63	2	119	3	16	1	47	0	63	1	24	36	25	5	0.00	0.33	0.50	0.15
7	51	50	0	61	4	20	1	130	5	115	2	20	47	22	8	0.00	0.67	0.67	0.12
8	53	64	0	61	4	8	0	29	2	76	1	13	39	17	7	0.43	0.22	0.61	0.18
9	55	54	1	85	5	16	0	31	4	161	2	31	42	29	7	0.00	0.67	0.56	0.06
10	58	67	1	72	4	7	0	15	1	33	2	17	42	19	9	0.00	0.22	0.50	0.06
11	59	54	1	83	5	18	1	70	7	110	2	26	60	28	7	–	–	–	–
12	66	55	0	122	3	9	0	29	1	120	1	13	26	19	6	0.43	0.33	0.61	0.06

Legend: VA=verbal ability score (mean Similarities and Naming Vocabulary Scale BAS); T=time in seconds; E=number of errors; VMI=Developmental Test of Visual-Motor Integration; mot=motor control and coordination; pro=representation of proportion; dep=depiction of particular features; det=awareness of detail in any feature.

Table B.2: Individual data on general motor competence, neurological status, vision, visual discrimination, sex, gestational age, birthweight and ultrasound abnormality for the 12 consistently slow children on the form boards.

Ss	Movement ABC					Touwen neurol. Exam.	Visual acuity	Visual discrimination			Sex	GA	BW	US Lesion
	Manual dext.	Ball skill	Balance	Tot.	CL			Matching shapes of MASH form board		Matching Letter-Like forms (BAS)				
	normative score				score	score	near	errors	time	T-score				
1	4.5	3.0	0.0	7.5	0.35	38	4.5	4	109	59	F	31	1340	Normal
2	5.5	0.0	1.0	6.5	–	41	4.5	5	118	46	M	28	910	I + Flares
3	0.0	0.0	0.0	0.0	0.21	44	6.0	2	104	52	M	30	1510	ventr. dilatation
4	0.0	3.0	0.0	3.0	1.12	40	4.5	4	100	54	F	32	1500	Infarct
5	6.0	5.0	0.5	11.5	–	42	4.5	4	127	63	F	29	910	Flares < 7 days
6	1.5	2.0	1.5	4.5	0.87	34	4.5	3	98	34	F	28	760	Grade I haem.
7	1.0	0.0	0.0	1.0	0.49	34	4.5	3	110	39	F	29	1160	Normal
8	0.0	1.0	0.0	1.0	0.50	45	4.5	2	96	54	F	31	1680	Normal
9	1.5	2.0	0.0	3.5	–	40	4.5	1	106	32	F	26	890	I + Flares
10	0.0	0.0	0.0	0.0	0.29	38	4.5	4	114	55	F	32	1390	Normal
11	7.5	0.0	1.0	8.5	0.84	32	4.5	6	117	37	F	29	840	Normal
12	2.0	2.0	5.0	9.0	0.49	45	4.5	3	102	40	M	30	960	Flares < 7 days

Legend: Tot.=total normative Movement ABC Test score; CL=Movement ABC Checklist scores; GA=gestational age; BW=birthweight; US=Ultrasound.

APPENDIX C

Repeated qualitative descriptions of performance on the MASH form board

Table C1.a: Repeated qualitative description of performance on the MASH form board for matched pair 2.

Slow child	Fast child
General behaviour good concentration	**General behaviour** good concentration
Strategy -slow, deliberate style -seems to lack concept of speed -perseveres in wrong attempts	**Strategy** -efficient strategy -overlap of activity of eye- and head-movements and hand-movements
Transport/insertion of shapes -finger movements not well differentiated -inaccurate insertion -switches from unimanual to bimanual when difficulties arise -poor preservation of orientation of shape in transport phase	**Transport/insertion of shapes** -fluent, short transport phase -preserves orientation of shape in transport phase -bimanual coordination
Visual and haptic feedback/exploration -does not seem to be able to process visual or haptic feedback	**Visual and haptic feedback/exploration** -hardly noticeable, rapid visual scanning of cavities
Observer 2:slow child *	Observer 2: fast child

* Observer 2 = SH

Table C.1b: Repeated qualitative description of performance on the MASH form board for matched pair 5.

Slow child	Fast child
General behaviour good concentration **Strategy** -does not seem to deal 'intelligently' with errors, i.e. perseveres in wrong attempts **Transport/insertion of shapes** -hesitant in transport phase -finger movements not well differentiated -initially unimanual, other hand assists when difficulties arise -does not preserve orientation of shape in transport phase **Visual and haptic feedback/exploration** -plenty of visual scanning of cavities -unable to act upon visual or haptic feedback	**General behaviour** good concentration **Strategy** -appears to plan movements ahead -sequence of picking-up shapes present **Transport/insertion of shapes** -smooth, goal-directed transport phase -dexterous, well differentiated finger movements -preserves orientation of shape in transport phase **Visual and haptic feedback/exploration** -efficient, quick eye-movements
Observer 2: slow child	Observer 2: fast child

Table C.1c: Repeated qualitative description of performance on the MASH form board for matched pair 8.

Slow child	Fast child
General behaviour good concentration **Strategy** -no clear search strategy -starts off well but seems 'lost' later on **Transport/insertion of shapes** -dexterous, neat finger movements -smooth insertion -unimanual **Visual and haptic feedback/exploration** -good use of visual feedback, i.e. swift error correction by immediately picking up other shape of pair -no apparent use of haptic feedback	**General behaviour** good concentration, alert and confident **Strategy** -well organised -able to do two tasks at same time, i.e. insertion and scanning of pick-up area **Transport/insertion of shapes** -smooth transport -neat finger movements -clean insertion -preservation of orientation of shape most of the time but nit always -unimanual **Visual and haptic feedback/exploration** - visually scans cavities in board well, swift eye-movements -'tapping' of shape after insertion (haptic reassurance)
Observer 2:slow child	Observer 2: fast child

Table C.1d: Repeated qualitative description of performance on the MASH form board for matched pair 10.

Slow child	Fast child
General behaviour good concentration **Strategy** -not an effective strategy, does not seem to plan actions **Transport/insertion of shapes** -bimanual -inaccurate insertion of shapes **Visual and haptic feedback/exploration** -no visual scanning of shape -does not seem to be able to process visual and haptic feedback	**General behaviour** keen, good concentration **Strategy** -eye and head movements ahead of hand movements -sensible strategy for correcting (few) errors **Transport/insertion of shapes** -fluent sequence of movements -unimanual -good independent finger movements -neat insertion -large movements overshooting the target (last visual check?) **Visual and haptic feedback/exploration** -actions seem visually driven
Observer 2: slow child	Observer 2: fast child