That is, there are difficulties in both the perceptual and the difficulty in using kinaesthesia 6, and in matching between to do so in term of behavioural tests (e.g. balance compared kinaesthesis and vision 7 • They have slower movement times, subdivided clum y chi ldren into different groups have tended between group of clumsy children on the basis of coordination which i reflected in poor purpo ive movement, difficulties are strongly indicated. There have been many attempts to separate such children from those whose development is following a normal course. Some have argued that children with cerebral palsy and those with mild to moderate perceptual-motor problems are on a continuum, other diagnostic criteria put children who do not shown signs of neurological dysfunction in a standard neurological examination into a separate group (e.g. the diagnostic criteria in DSM IIIR 1987). Nevertheless, there is agreement that children with “developmental coordination disorder” or “clumsy child syndrome” have an impairment of coordination which is reflected in poor purposive movement, in the absence of other intellectual or physical impairment. Several studies 4 have reported that there may be a history of difficulties in labour, complications during pregnancy, prematurity, low birth weight, and neonatal problems, in children who are identified as clumsy at school age. Others have argued that learning experience may be restricted in such children, or that genetic factors may be involved. Aetiology may therefore be multi-factorial, but perinatal and neonatal difficulties are strongly indicated.

One of the difficulties in understanding the nature of the underlying problem in clumsy children is that they are not a homogeneous group, and they show a range of difficulties with different kinds of perceptual motor tasks. In group studies, however, clumsy children have been found to have impaired use of sensory information for the control of movement, difficulty in using kinaesthesia, and in matching between kinaesthesia and vision. They have slower movement times, longer reaction times, less accurate movements to targets, difficulties in producing appropriate force, and some difficulties in using vision to modulate movement control. That is, there are difficulties in both the perceptual and the motor elements in movement control. Studies which have subdivided clumsy children into different groups have tended to do so in terms of behavioural tests (e.g. balance compared with sequencing) and have not attempted to find underlying deficits which separate these groups. Attempts to differentiate between groups of clumsy children on the basis of neurological soft signs have indicated that some children have a relatively greater impairment in controlling force output than they do in controlling movement timing, while others show the reverse pattern of disability 2. This suggests that the motor system may be noisy in children with minor neurological signs, and therefore more difficult to control. As perceptual motor development depends on the regulation of movement under sensory control, it is not clear which, if any, of these observations are the most important component of the coordination problem found in these children.

In the work which we have been carrying out with clumsy children, we have been attempting to understand the problems faced by the children in the context of accounts of normal perceptual motor development. In normal development babies reach towards objects and subsequently modulate their reaching behaviour according to the direction of the object, its distance away, and its orientation. These changes may be due to developing perceptual systems, to changes in the muscle system at the periphery (e.g. increased muscle strength), or to changes in the organisation of the pattern for reach and grasp, reflecting central nervous system development, or to combinations of these. A central question for normal motor development concerns how these changes occur. One argument is that an infant produces a wide repertoire of movements, only some of which are successful. These successful movements may not be the most efficient movements in terms of the amount of energy expended and the comfort or awkwardness of the positions which the limb takes throughout the trajectory. Inefficient movements subsequently disappear from the normal repertoire, although they can be called upon when necessary - if, for example, an adult has to reach round something to pick up an object and so takes up a less comfortable arm position. A child who does not have normal kinaesthetic information about the success and efficiency of actions may not be able to stabilise on efficient patterns of movement and so is awkward or clumsy.

Using an account of development of this kind we can explore the relationships between sensory factors and the planning of smooth skilled action in children. In work which we have been carrying out recently, and which is now being funded by the MRC, we are investigating how children reach out to pick up an object when they know they have to do something with it. This is a kind of action planning, although it is planning on a very small scale. When adults and older children reach for objects they open the fingers during the trajectory, and this opening is timed to occur as velocity reaches its maximum. The fingers open more for larger objects, but they always open further than the object size in the middle of the reach then close before the grasp is made. If the target object is fragile the movement decelerates earlier than it does if the object is a robust one. Knowledge about objects informs the way in which we move our hands towards them.
Knowing what we are going to do with objects also affects the way we reach for them. Imagine a waiter picking up an upside down glass from a table, in order to fill it with wine. The hand is open, the little finger is toward the ceiling and filled. The waiter has sacrificed comfort in the preliminary reach in order to maximise stability and comfort as the wine is poured. A waiter who did not select the correct grasp would have to hold the hand in a twisted position, or even use two hands, or put the glass down and pick it up again. All of these would look awkward and clumsy. Children who do not learn to select the most efficient pattern of action from those available to them, will also be clumsy, because they have to make continuous correction during execution, use more extreme joint angles, and do not optimise stability.

We have used a very simple task, first described by Rosenbaum et al (1990). A wooden bar rests on a cradle (see Figure 1). The task is simply to pick up the bar and rest one end on one of the disks. If the black end of the bar is to be put on the black disk, an underhand grip will lead to a comfortable final position for a right handed person, and if the grey end is to be put on the grey disk, an initial overhand grip will lead to a comfortable final position. Adults presented with this task select the appropriate grip 100% of the time. We asked clumsy children and children matched on age, gender and verbal IQ, to carry out this task twelve times. The data in Table 1 indicate that normal children change towards the adult grasp pattern between age 6 and age 8. Clumsy children at age 6 do not differ from chance in their selection of the appropriate over- or underhand grip, and although they improve by age 8, they are not at the level of the 8 year old control children. This extremely simple task indicates that by age 6 clumsy children have not acquired the ability to select an appropriate grasp.

![Figure 1](/images/rod_to_disk_task.png)

**Figure 1** - The rod-to disk task. The rod rests on wooden cradles. Subjects were asked to pick up the rod and to rest one end on one of the two disks.

<table>
<thead>
<tr>
<th>Age  (years)</th>
<th>Clumsy children</th>
<th>Control children</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 years</td>
<td>51.7</td>
<td>74.8</td>
</tr>
<tr>
<td>7 years</td>
<td>70.1</td>
<td>72.9</td>
</tr>
<tr>
<td>8 years</td>
<td>72.1</td>
<td>91.5</td>
</tr>
</tbody>
</table>

Table 1 – Mean percentage correct scores on the bar-grasping task for clumsy children and age-matched controls

One of the other tests used in this study was a sub test of a neuropsychological test battery for young developmentally disabled children. In this test the experimenter places one of the child’s arms and hands in a set position and the child is required to move the other arm and hand into a matching position, keeping the eyes closed throughout. This allows some assessment to be made of the ability of the child to match felt limb position. The clumsy children in our study were poorer at this kinaesthetic matching task (see Table 2) than their age-matched controls, and in addition, this task predicted a significant proportion of the variance in the bar grasping task. Clumsy children who had more difficulty with the kinaesthetic matching task also had less stable use of relevant over- and underhand grips.

<table>
<thead>
<tr>
<th>Age  (years)</th>
<th>Clumsy children</th>
<th>Control children</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 years</td>
<td>2.4</td>
<td>7.0</td>
</tr>
<tr>
<td>7 years</td>
<td>4.7</td>
<td>6.5</td>
</tr>
<tr>
<td>8 years</td>
<td>4.8</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Table 2 – Mean scores on a kinaesthetic matching task for clumsy children and age-matched controls (maximum score = 8)

Our current work is concerned to extend these findings, and to explore further the suggestion that the inability to use sensory input may be related to an inability to select appropriate action. If it is difficult to detect the relevant information about the comfort of joint angles and therefore to learn to select those which minimise rotation, it may well be difficult to develop competent organisation of sequences and patterns of movement. The problems faced by the clumsy child may inform us about the developmental course of the organisation of action in all children.

A distinction is sometimes drawn between children who have coordination disorder and children who have developmental dyspraxia. This distinction can be based on a separation between those who know what the movements are they wish to carry out but have an impairment in execution, and those who find it difficult to plan movements but do not have an impairment of execution. In practice, little attempt is sometimes made to distinguish between these two, and one difficulty is that in developmental terms it is hard to distinguish between a disorder of planning and one of execution when the development of each is dependent on the other. The adult apractic patient may be tested on the production of skilled action to command, the pantomiming of gestures to command, and the imitation of gestures, but this is not appropriate in the developmental case. All actions extend over time and therefore may involve some element of planning, even if the actor is not aware of all the elements which must be organised. A more detailed analysis of the interrelationship between organisation and execution during development is needed before clear distinctions between dyspraxia and clumsiness can be made. If there are conceptual difficulties then the child is usually having problems in other areas as well as in perceptual motor skill.

Why does clumsiness matter? One answer is that it is interesting in itself, and that it may help us to understand the normal course of motor development. However, it also matters for the children who suffer from it. Perceptual motor skill is extremely salient, both socially and intellectually, in the early years of school life. It is not peripheral to the life of the developing child in our culture, but is central to it and may have far reaching effects in social and intellectual development. Perceptual motor performance improves for some children during their secondary school years so that at age 15 they can no longer be discriminated from control children on a range of perceptual motor tasks. Others retain their coordination problems into late adolescence and adulthood. There is evidence from several follow-up studies which suggests that early lack of competence in perceptual motor tasks is related to poor academic success in adolescence, and less satisfactory social relations with peers and with adults. Understanding of the developmental issues in perceptual motor performance of the clumsy child may have consequences for remediation, which in turn can have far reaching effects on general intellectual and social development.
References


