CHAPTER 1

WINDOWS ON THE BRAIN

INTRODUCTION

Although all learning ultimately takes place in the brain, it is often forgotten that it is through the body that the brain receives sensory information from the environment and reveals its experience of the environment. Postural control reflects integration of functioning within the central nervous system (CNS) and supports brain–body functioning. Immaturity or conflict in brain–body functioning affects the brain’s ability to assimilate and process information and to express itself in an organized way.

One method of assessing maturity and integrity in the functioning of the CNS is through the examination of primitive and postural reflexes. The presence or absence of primitive and postural reflexes at key stages in development provides ‘windows’ into the functioning of the CNS, enabling the trained professional to identify signs of neurological dysfunction or immaturity.

This book, I hope, will give the reader an understanding of why early reflexes are important, their functions in early development, their effects on learning and behaviour if retained, and the possible effects on other aspects of development such as posture, balance, and motor skills if they are not integrated at the correct time in development.

There is an increasing body of scientific evidence to support the theory that physical skills support academic learning and are involved in emotional regulation and behaviour. Since its foundation in 1975, The Institute for Neuro-Physiological Psychology (INPP) in Chester has been the pioneer in researching the effects of immature primitive and postural reflexes on learning and behaviour, developing protocols for the assessment of abnormal reflexes and related
functions, and has devised a specific method of effective remediation (The INPP Method).

Research carried out both independently and by The Institute over the last 30 years has shown that there is a direct link between immature infant reflexes, academic underachievement and increased anxiety in adult life, and that a remedial programme aimed directly at stimulating and integrating primitive and postural reflexes can effect positive change in these areas. This book will outline the underlying theory, mechanisms, developmental markers, and effects of immature reflexes in the older child to assist professionals involved in education and child welfare to recognize the signs of neurological dysfunction and their implications.

The book will also explore interdisciplinary shortcomings endemic in the current system for identifying, assessing, and providing effective remedial intervention for learning and behavioural problems. In this context, the book will propose that there is a need within education for a new profession to bridge the present gaps – a neuro-educator – trained specifically to assess children’s developmental readiness for education.

**DEVELOPMENTAL READINESS FOR EDUCATION**

Chronological age and intelligence are not the only criteria for learning success. Developmental readiness for formal education is equally important. Developmental testing of motor skills is carried out regularly in the first year of life, but when responsibility for the young child moves from the domain of medicine (midwife, paediatrician, and health visitor) to education at the time of school entry, a child’s developmental readiness in terms of physical development is not assessed as a matter of routine. Once a child enters formal education at rising five years of age in the UK, assessment of physical development only takes place if problems of a medical nature arise. Assessment within the school system tends to focus on the educational problems or the presenting symptoms rather than on the investigation of underlying causes.
The INPP in Chester was set up in 1975 by psychologist Peter Blythe, PhD, with the aim of investigating whether underlying physical factors could play a part in specific learning difficulties and in some phobic disorders. In the 1970s, Peter Blythe and David McGlown devised, first, systems of assessment to identify areas of impaired functioning, and second, physical remediation programmes to correct the underlying dysfunctions. These methods of assessment, which involve examining the neuro-developmental level of the child and the subsequent physical programmes of remedial intervention, are now known as The INPP Method of Developmental Training.

By their very nature, symptoms of specific learning difficulties tend to cross diagnostic boundaries, with different categories sharing a number of symptoms in common (co-morbidity). This is particularly true of many of the symptoms of dyslexia, developmental coordination disorder (DCD), attention deficit disorder (ADD), and some aspects of autistic spectrum disorders. A number of the symptoms shared in common are a direct result of immaturity in the functioning of the CNS and are sometimes referred to as neurological dysfunction or neuro-developmental delay.

**WHAT IS NEURO-DEVELOPMENTAL DELAY?**

Every normal human baby, born at full term (40 weeks’ gestation) is equipped with a series of primitive reflexes to help it survive the first few weeks and months of life. If one side of the mouth is gently stroked, the neonate will turn its head in the direction of the stimulus and the mouth will open, searching or ‘rooting’ for the breast; if a finger is placed inside the baby’s mouth, it will reflexively start to suck, and if an object is placed in the palm of its hand, it will grip and not be able to let go at will. These primitive reflexes are hard-wired into the brainstem at birth. They are active for the first six months of life, but from the moment of birth, they start a gradual process of inhibition by higher centres in the brain as neurological connections to higher centres develop. As the primitive reflexes are inhibited, the postural reflexes emerge, which gradually take over many of the functions of the primitive reflexes. Postural reflexes take up to three and a half years of age to be fully developed.
Neuro-developmental delay, sometimes also referred to as neurological dysfunction, is defined by the INPP as (1) the continued presence of a cluster of aberrant primitive reflexes above six months of age and (2) absent or underdeveloped postural reflexes above the age of three and a half years. The presence or absence of primitive and postural reflexes at key stages in development provides evidence of immaturity in the functioning of the CNS and will influence the development and control of posture, balance, and motor skills.

WHAT IS THE CONNECTION BETWEEN NEURO-DEVELOPMENTAL DELAY AND SPECIFIC LEARNING DIFFICULTIES?

Successful academic learning relies upon adequate mastery of motor skills: reading, for example, involves development and control of smooth eye movements to send an orderly flow of sequential information to the brain; eye movements are a motor skill. In order to write, a child needs to have developed hand–eye coordination; this is also a motor skill. Sitting still and paying attention require postural control, balance, and orientation, in addition to the involvement of cortical centres implicated in the maintenance of attention; aspects of mathematics require spatial skills and cooperation between the two sides of the cerebral cortex (left and right hemispheres) to cooperate in solving problems in a sequential fashion. Many of these ‘higher’ cognitive processes are rooted neurophysiologically in systems involved in postural control, and the reflexes play a crucial part in supporting and facilitating stability and flexibility in postural control.

Spatial skills develop directly from physical awareness of the body position in space. Secure balance is fundamental to navigation in space because it provides the physical basis for a secure internal reference point from which spatial judgements about the external environment are formed. Dr Harold Levinson described the vestibular-cerebellar system as acting as ‘a compass system. It reflexively tells us spatial relationships such as right and left, up and down, front and back, east and west, north and south’.

Research has shown that perception and differentiation of sequences of mobile stimuli, known to be related to vestibular and cerebellar mediation and postural stability, are faulty in children with
reading difficulties. The cerebellum is also linked to the ability to sequence not only motor tasks but also associated cognitive processes.

Inter-hemispheric functioning, which is essential for problem solving, is reflected in a child’s ability to use the two sides of the body in different ways. In addition to the specific brain centres which are involved in the mediation and control of balance, integration in the use of the two sides of the body both reflects and supports the use of balance, bilateral integration. While many of the areas of the brain are involved in different types of learning, higher cognitive functions rely upon the integrated functioning of lower centres to support and to feed information to the cortex.

Primitive and postural reflexes at key stages in development provide a ‘window’ into the structural and functional integrity of the hierarchy of the brain. Abnormal primitive and postural reflexes provide diagnostic signs of immaturity in the functioning of the CNS which can interfere with optimal cortical functioning. The central nervous system acts as a coordinating organ for the multitude of incoming sensory stimuli, producing integrated motor responses adequate to the requirements of the environment. When the CNS is working well, the cortex is free to concentrate on ‘higher’ functions, being involved in intention and motor planning, but not the detailed mechanics of movement. ‘The cortex knows nothing of muscles, it only knows of movement.’

This is because voluntary movements, particularly those associated with postural adjustment, are largely automatic and function outside of consciousness. The maintenance of posture and equilibrium is carried out by the CNS recruiting lower centres in the brainstem, midbrain, cerebellum, and basal ganglia in the service of the cortex.

PRIMITIVE AND POSTURAL REFLEXES – THE MEDICAL MODEL

It is medically accepted that abnormal reflexes can persist as a direct result of pathology such as in cases of cerebral palsy when damage to higher brain centres prevents the cortex from completely inhibiting the primitive reflexes in the first year of life or from releasing postural reflexes.
Primitive reflexes may also reappear as a result of progressive pathology such as in multiple sclerosis when pinhead-sized hardened patches develop and scatter irregularly through the brain and the spinal cord, causing the insulating sheaths of the nerve fibres in the hardened patches to break up and become absorbed, leaving the nerve fibres bare. When this happens, postural reflexes become impaired and the primitive reflexes re-emerge as a direct result of loss of integration within the functioning of the nervous system and loss of control from higher centres. A similar regression of reflex integration can be seen in Alzheimer’s disease, when degeneration within the cerebral cortex results in gradual loss of higher cortical function and the release of primitive reflexes as primitive, protective, survival mechanisms.

The transition from primitive to postural reflex in the first year(s) of life is a gradual one. It occurs as a result of maturation within the CNS, but it is also partly environmentally dependent. While the reflexes are hard-wired into the system at birth, physical interaction with the environment is like the software through which the potential of the nervous system is entrained. In the early months of life, primitive reflex actions provide rudimentary physical training through movement at a time in development before the cortex and connections to the cortex are sufficiently mature to orchestrate a controlled response. In other words, through the feedback or movement experience of early reflex actions, neurological pathways are developed and strengthened. As connections between higher and lower centres become established, primitive reflexes are inhibited to make way for more advanced systems of voluntary movement and postural control.

At this stage of development, postural reflexes lay the foundations for automatic reactions needed for the maintenance of posture and balance in a gravity-based environment (preconscious), as well as support the control of voluntary movement. The importance of postural reflexes in supporting automatic reactions and in reducing the workload of the cortex was described as early as 1898 by Reuben Halleck in a book *Education of the Nervous System* when he explained how ‘reflex action is the deputy of the brain, and directs myriad movements, thus leaving the higher powers free to attend to weightier things.’
It should be stressed that the primitive reflexes never entirely desert us. The process of inhibition puts them to sleep in the brainstem only to be reawakened if disease, accident, or injury results in damage to higher brain centres. In this way, primitive reflexes continue to remain available to fulfil a protective function if required. However, the concept that abnormal primitive and postural reflexes can persist in the general population is still controversial, despite an increasing body of evidence to support the theory that abnormal primitive and postural reflexes can and do exist in the absence of identified pathology.\textsuperscript{7–15}

The effects of retained primitive reflexes and underdeveloped postural reflexes in the older child are well documented.\textsuperscript{16–19} It is also recognized that aberrant reflexes can affect higher cortical functioning particularly in the area of education,\textsuperscript{17,20,21} but 30 years after much of this research has been published, the concept that reflex status can interfere with cognitive performance still remains controversial. The role of abnormal reflexes in dyslexia as a discreet entity has never been conclusively established despite the fact that dyslexia is sometimes categorized as a developmental and neurological disorder.\textsuperscript{22}

**How Can Testing of Primitive and Postural Reflexes Be Used?**

Primitive and postural reflexes can be used as clinical tools to

- identify signs of immaturity in the CNS (diagnosis);
- provide indications as to type and developmental level of intervention (appropriate treatment);
- measure change (clinical evaluation).

**NEUROLOGICAL DYSFUNCTION IN SPECIFIC LEARNING DIFFICULTIES**

By their very nature, symptoms of specific learning difficulties tend to cross diagnostic boundaries, with different categories sharing a number of symptoms in common. This is because ‘common neurophysiological functions which feed and control postural mechanisms are fundamental to higher
ATTENTION, BALANCE, AND COORDINATION

cognitive processes.\textsuperscript{23} They affect developmental aspects of motor, vestibular, and postural functions including

- visual and acoustic sequence processing;
- inadequate perception;
- graphic representation of geometrical forms;
- confused spatial organization;
- poor short-term memory;
- clumsiness;
- deficits in surface and deep structure language.

While the individual features of each category are unique to the condition, there is often an overlap in many presenting symptoms (co-morbidity). When areas of shared dysfunction are present, they are indicative of immaturity in the functioning of the CNS.

A number of years ago, a cluster of some of these signs and symptoms would have been described collectively under the more general and now redundant term of minimal brain dysfunction (MBD). This term was discarded in the 1960s and early 1970s, partly because there were over 99 symptoms listed under MBD with at least 10 major symptoms, making it too broad a definition on which to base or select effective clinical intervention. Nevertheless, MBD was an attempt to describe a ‘grey area’ between the disciplines of medicine, psychology, and education by listing a cluster of symptoms for which there was no clear pathology at the time.

In many cases, when co-morbidity is present, further investigations do reveal a general immaturity in the functioning of the CNS, which can be confirmed by a cluster of aberrant reflexes in the older child. The reasons for immature reflex development in the first year or years of life are generally multifactorial, but possible early signs of delay in reflex integration can be seen in a child’s developmental profile, and some of these developmental markers will be explored further in Chapters 6 and 7. In the same way, the effects of aberrant reflexes on a child vary according to age and reflex profile of the individual child. Individual reflexes, their functions, and effects will be the subject of Chapters 2–5, which will examine the role of reflexes in early development and their impact on learning. Immaturity in the control of the body can affect educational achievement and behaviour.

The first ABC a child learns is the ABC of the body — the foundation on which cognitive learning is built and the mode through which it is expressed:

\textbf{A = Attention} \quad \textbf{B = Balance} \quad \textbf{C = Coordination} = developmental readiness for educational achievement.
in a number of ways. Attention, balance, and coordination are the first ABC on which developmental readiness for education is built.

DIAGNOSTIC CRITERIA, SIGNS, AND SYMPTOMS OF SPECIFIC LEARNING DIFFICULTIES

When parents first become aware that their child is experiencing difficulties, they are usually anxious to find a reason and/or a term to describe their child’s problem. The child may be referred for assessment, and if the combination of problems fits into a recognized category, a diagnosis or label will be given. This diagnosis provides a description of a specific group of symptoms and indicates which types of intervention are likely to be helpful, but diagnosis in the area of specific learning difficulties does not always explain why the problem has developed, nor does it identify specific underlying mechanisms at fault. In other words, diagnosis in the area of educational difficulties frequently tells us what is wrong, but rarely reveals why it has happened.

In order to understand how and why postural problems can be factors in many specific learning difficulties, it is necessary to look at some of the individual features of specific learning difficulties and some of the possible underlying factors at a physical level which may be playing a part in the presenting symptoms (Figures 1.1 and 1.2).

Figure 1.1  Co-morbidity of symptoms in specific learning difficulties: dyslexia
Each of the specific learning difficulties mentioned above shares impairment in the perception, organization, or execution of controlled movement: attention deficit hyperactivity disorder (ADHD), for example, involves inadequate inhibition of movement and inhibition of arousal to competing sensory stimuli. An important feature of dyspraxia or DCD is the inability to integrate sensory-motor experience and to organize motor output; children with dyslexia who have visual processing and motor-perceptual problems have difficulty with understanding direction, sequencing, and control of eye movements. Additionally, a large percentage of children with dyslexia also have phonological processing problems. Phonological and visual processing problems are often treated as discrete entities, even though hearing and listening also involve the perception of motion within a specific range of frequencies. Children diagnosed on the autistic spectrum suffer from disintegrated or fragmented sensory perception.

**DYSLEXIA – SIGNS AND SYMPTOMS**

**Dyslexia**

Dyslexia was defined by the World Federation of Neurology in 1968 as ‘a disorder in children who, despite conventional classroom experience, fail to attain the language skills of reading, writing and spelling commensurate with their intellectual abilities.’ More recently, this definition has
been expanded and described as ‘a complex neurological condition which is constitutional in origin. The symptoms may affect many areas of learning and function and may be described as a specific difficulty in reading, spelling and written language. Additionally, one or more of the following areas may be affected: Numeracy, notational skills (music), motor function and organisational skills. However, dyslexia is particularly related to mastering written language, although oral language may be affected to some degree.’

Associated symptoms
In addition to problems with reading, spelling, and written language expression, children with dyslexia often manifest problems with motor skills such as hopping and skipping, catching and throwing a ball; learning to ride a bicycle, coordination at gym and sometimes at swimming; and problems with directionality, such as telling left from right, laying a table correctly, and telling the time from an analogue clock. Problems with fine muscle skills may include difficulties tying shoelaces, doing buttons up, and manipulating a writing instrument. Sequencing, visual memory, and auditory perception may also be affected, and there may be ambiguity of laterality. Performance in these areas is dependent upon the maturity of the reflex system which underlies motor learning, vestibular functioning, and kinesthetic integration.

Neurological factors in dyslexia
Ever since dyslexia was first identified, it has been hypothesized that structural abnormalities in the brain may underlie the disorder. Post-mortem examination of the brains of five male and three females who had dyslexia revealed two consistent findings in the group: developmental neuropathology and symmetry of language-related regions of the brain.

Over the last 40 years, research into dyslexia has focused upon four main areas of difficulty:

1. Difficulties with automatic balance originating from dysfunction in the vestibular-cerebellar loop;
2. Immature motor skills;
3. Auditory processing problems\textsuperscript{39,40} and the phonological deficit theory\textsuperscript{41–45}
4. Abnormal processing of visual information\textsuperscript{46–48}

In 1996, Fawcett and Nicolson\textsuperscript{33} concluded that ‘children with dyslexia have deficits in phonological skill, speed of processing and motor skills. These deficits are well characterised as problems in skill automatisation, which are normally masked by the process of conscious compensation.’ Many other causal and contributory factors have also been suggested including differences in left hemisphere functioning, structure of the thalamus\textsuperscript{49} – an area of the brain involved in processing and filtering sensory information – and genetic susceptibility for developmental dyslexia\textsuperscript{50}.

Inheritable tendency through the male line has been associated with phonological processing problems. This may be because men have only one gene responsible for phonological processing, whereas women have two. If the gene responsible for phonological awareness, rapid naming, and verbal short-term memory is affected, males are less able to compensate for the problem. Females tend to use the language centres located in each cerebral hemisphere with greater flexibility than males. This may be in part due to the fact that the corpus callosum has been found to be larger in relation to brain weight and is more bulbous in females than in males, presumably facilitating increased inter-hemispheric communication.

The automization of skills depends upon the maturity of the subcortical supporting systems within the brain, of which the primitive and postural reflex system (mediated at the level of the brainstem and the midbrain) is one of those underlying structures. Postural reflexes are important for maintenance of posture and the execution of controlled movements in cooperation with other centres such as the cerebellum, basal ganglia, and motor cortex.

Features of dyslexia:
- More common in males;
- Tends to run in families;
- Developmental history of clumsiness and minor speech impairments in rote learning (sequencing) such as learning the alphabet, days of the week, months of the year, multiplication tables, etc.
• Marginally late developmental milestones such as crawling (may have omitted crawling stage), walking, talking, and reading.

Difficulty with the following:

• ambi- or cross-laterality;
• telling left from right;
• letter and number reversals when reading and writing above the age of eight years;
• spatial reversals, mirror writing, and misordered letters;
• losing place when reading;
• following instructions (Tables 1.1–1.6).

Laterality

There is ambiguity of laterality or cross-laterality. Lack of lateral preference can occur for many reasons. Some of these will be covered in subsequent chapters (Tables 1.7 and 1.8).

**DCD (DYSPRAXIA)**

Dyspraxia means difficulty with praxis, praxis being a derivation of the Greek word for ‘action’. Formerly described as the clumsy child syndrome, the term dyspraxia has currently been replaced by DCD. DCD is defined by the *Diagnostic Statistical Manual of Mental Disorders*53 as

A marked impairment in the development of motor coordination (criterion A). The diagnosis is made only if this impairment significantly interferes with academic achievement or activities of daily living (criterion B). The diagnosis is made if the coordination difficulties are not due to a general medical condition.

**Criterion A**

Performance in daily activities that require motor coordination is substantially below that expected given the person’s chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones, dropping things, poor performance in sports or poor handwriting.
<table>
<thead>
<tr>
<th>Motor skills</th>
<th>Symptom</th>
<th>Subcortical mechanisms/systems involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross motor skills</td>
<td>Hopping, skipping, forward rolls</td>
<td>Balance, sequencing of movements (cerebellum), and upper/lower body integration</td>
</tr>
<tr>
<td></td>
<td>Catching, throwing, and kicking a ball</td>
<td>Hand/eye, eye/foot coordination</td>
</tr>
<tr>
<td></td>
<td>Clumsy when going upstairs</td>
<td>Left/right, upper- and lower-body coordination</td>
</tr>
<tr>
<td></td>
<td>Marginally late developmental milestones, e.g. crawling, walking, talking, and reading</td>
<td>Balance, posture, bilateral integration</td>
</tr>
<tr>
<td></td>
<td>Learning to ride a bicycle</td>
<td>Vestibular, postural and bilateral integration</td>
</tr>
<tr>
<td></td>
<td>Learning to swim</td>
<td>Poor upper- and lower-body and left/right coordination</td>
</tr>
<tr>
<td></td>
<td>Coordination at gym, climbing a rope, working with an apparatus</td>
<td>Vestibular, postural, hypotonic, upper- and lower-body integration</td>
</tr>
<tr>
<td>Fine motor skills</td>
<td>Difficulty using equipment, e.g. scissors, cutlery</td>
<td>Fine motor skills, dysdiadochokinesis (cerebellum and motor cortex)</td>
</tr>
<tr>
<td></td>
<td>Immature or awkward pencil grip</td>
<td>Retained reflexes affecting manual dexterity</td>
</tr>
<tr>
<td></td>
<td>Difficulty learning to tie shoelaces, do buttons up, etc.</td>
<td>Fine motor skills, directionality (vestibular), left/right integration</td>
</tr>
</tbody>
</table>
**Table 1.2** Directionality problems in dyslexia

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Underlying mechanisms/systems involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left/right, up/down, before/after discrimination</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>Orientation</td>
<td>Vestibular</td>
</tr>
<tr>
<td>Laying a table correctly</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>Putting clothes on the right way round</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>Following or giving directions</td>
<td>Auditory processing, sequential processing (cerebellum), directional (vestibular)</td>
</tr>
<tr>
<td>Jigsaw puzzles and mazes</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>Learning to tell the time from an analogue clock</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>History of motion sickness which continues beyond puberty</td>
<td>Vestibular-visual-proprrioceptive mismatch</td>
</tr>
</tbody>
</table>

**Table 1.3** Speech and language symptoms in dyslexia

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Underlying mechanisms/systems involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter, number, and word reversals</td>
<td>Directionality (vestibular), auditory discrimination and/or sequencing (phonological/cerebellum), lateral organization</td>
</tr>
<tr>
<td>Word-naming problems</td>
<td>Visual and/or auditory recognition and recall; inter-hemispheric communication</td>
</tr>
<tr>
<td>Mispronunciation</td>
<td>Auditory and oral-motor discrimination</td>
</tr>
<tr>
<td>Confusion/substitution of wrong words</td>
<td>Auditory and/or visual discrimination (reading)</td>
</tr>
<tr>
<td>Poor use of syntax</td>
<td></td>
</tr>
<tr>
<td>Difficulties with rhyme and alliteration</td>
<td>Sequencing, auditory discrimination, inter-hemispheric communication</td>
</tr>
<tr>
<td>Hesitant speech</td>
<td></td>
</tr>
<tr>
<td>Poor memory for new words and word recall</td>
<td>Coding and retrieval</td>
</tr>
</tbody>
</table>
### Table 1.4  Sequencing problems in dyslexia

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rote learning</td>
<td>Cerebellum, inter-hemispheric communication</td>
</tr>
<tr>
<td>Board games that involve planning a series of moves</td>
<td>Spatial (vestibular), procedural (cerebellum); forward planning (frontal lobes), procedural memory</td>
</tr>
</tbody>
</table>

### Table 1.5  Visual symptoms in dyslexia

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter, word, number reversals</td>
<td>Directional (vestibular), visual (unstable supporting postural mechanisms), laterality, auditory delay</td>
</tr>
<tr>
<td>Mirror writing</td>
<td>Directional (vestibular)</td>
</tr>
<tr>
<td>Poor memory for word shape and pattern</td>
<td>Visual processing (right hemisphere)</td>
</tr>
<tr>
<td>Poor memory for detailed features of words</td>
<td>Left hemisphere, phonological processing</td>
</tr>
<tr>
<td>Scotopic sensitivity syndrome (SSS)</td>
<td>Immaturity in the visual system’s response to light</td>
</tr>
<tr>
<td>Difficulties with visual tracking</td>
<td>Underdeveloped postural mechanisms which support oculomotor functioning</td>
</tr>
<tr>
<td>Letter, word blurring/movement/omission</td>
<td>Poor near-point convergence</td>
</tr>
</tbody>
</table>

**SSS**
The nerve endings at the back of the retina of the eye are relayed to the thalamus, an area of the brain involved in filtering sensory information before it reaches the cortex, by two specialized types:

1. small cell bodies concerned mostly with colour hues and contrast (parvocellular pathways);
2. large cell bodies concerned mostly with movement

detection (magnocellular pathways).

A body of research indicates that in dyslexia, these cell bodies do not differentiate their functions adequately, resulting in visual dysfunctions and overlapping of functions between the two pathways.

Evidence suggests that dysfunctions in the magnocellular pathways are responsible for difficulties with visual motion detection in dyslexia.

The effect of dysfunction in the relationship between the two pathways is problems with perception of form when there is high contrast between dark print on a white background.
### Table 1.6 Auditory symptoms in dyslexia

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confusion or inability to hear the difference between different sounds</td>
<td>Auditory discrimination – may be connected to a history of frequent ear, nose, or throat infections in the first 3–5 years of life</td>
</tr>
<tr>
<td>Difficulty in processing auditory information</td>
<td>Laterality of auditory processing</td>
</tr>
<tr>
<td>Difficulty repeating rhymes</td>
<td>Sequencing (cerebellum), music of language (right hemisphere)</td>
</tr>
<tr>
<td>Difficulty following sequential instructions</td>
<td>Auditory delay (laterality of auditory processing), cerebellum, short-term memory</td>
</tr>
<tr>
<td>Difficulty in clapping or tapping out rhythms</td>
<td>Vestibular</td>
</tr>
</tbody>
</table>

### Table 1.7 Phobic disorders in dyslexia

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fear of the dark, heights, new places</td>
<td>Poor orientation in the absence of visual points of reference (vestibular/propropioceptive)</td>
</tr>
<tr>
<td>Fear/avoidance of motor-related activities</td>
<td>Immature coordination and postural control</td>
</tr>
<tr>
<td>Mood disturbances</td>
<td>Performance anxiety, frustration, orientation problems, biochemical, hormonal</td>
</tr>
<tr>
<td>Obsessive–compulsive tendencies</td>
<td>Increased metabolic activity in left orbital gyrus, deficiency in availability of the neurotransmitter serotonin, heightened glucose metabolism in the frontal lobes</td>
</tr>
</tbody>
</table>

### Table 1.8 Psychosomatic symptoms in dyslexia

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headaches</td>
<td>Visual stress, structural misalignment (skeletal)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>Vestibular, visual, low blood pressure</td>
</tr>
<tr>
<td>Motion sickness</td>
<td>Vestibular-ocular-propropioceptive mismatch</td>
</tr>
<tr>
<td>Bed-wetting</td>
<td>Neurological immaturity; persistent ear, nose, or throat infections resulting in congestion; retained spinal Galant reflex</td>
</tr>
<tr>
<td>Free-floating anxiety</td>
<td>Vestibular dysfunction and/or postural control resulting in gravitational insecurity, poor spatial awareness, perceptual problems, and difficulty coding environmental stimuli</td>
</tr>
</tbody>
</table>
**Criterion B**

- The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living.
- The disturbance is not due to a medical condition and does not meet the criteria for a pervasive developmental disorder.
- If mental retardation is present, the motor difficulties are in excess of those usually associated with it.

DCD is characterized by impairment or immaturity in the organization of movement. This involves problems with coordination of sensory-motor functions. Jean Ayres, an American occupational therapist who developed the system of sensory-motor training known as *Sensory Integration*, explained the problems of the clumsy child as stemming from difficulty with the *visualization, ideation* (motor planning), and *execution* of voluntary movement. In addition to motor problems, the child with DCD can also have associated problems with perception, language, thought, and behaviour. These are usually a secondary outcome of the primary sensory-motor coordination problem. Symptoms of DCD fall into three main categories: motor coordination, perceptual functioning, and learning abilities (Tables 1.9 and 1.10).

This combination of motor and sensory problems can then affect learning ability in a number of ways.

**Learning Problems**

- Attention and concentration;
- Organizational difficulties;
- Poor visual and auditory coding and memory;
- Writing;
- Coping;
- Reading;
- Presentation of work.

Some signs and symptoms are specific to one particular diagnostic category, while others are shared by all.
### Table 1.9  Motor coordination symptoms in DCD

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotonia (low muscle tone), which can manifest itself in poor posture and fatigue</td>
<td>Vestibular/postural, often linked to a retained symmetrical tonic neck reflex</td>
</tr>
<tr>
<td>Lack of coordination in the use of the two sides of the body</td>
<td>Bilateral integration, sometimes linked to a retained asymmetrical tonic neck reflex</td>
</tr>
<tr>
<td>Vertical midline problems</td>
<td>Retained asymmetrical tonic neck reflex</td>
</tr>
<tr>
<td>Poor balance</td>
<td>Vestibular, postural, and immature righting reflexes and equilibrium reactions</td>
</tr>
<tr>
<td>Lack of truncal differentiation</td>
<td>Upper- and lower-body integration (symmetrical tonic neck reflex)</td>
</tr>
<tr>
<td>Need to learn and practise motor tasks; practice does not make permanent</td>
<td>Cortical compensation for immature postural control, poor bilateral integration</td>
</tr>
<tr>
<td>Directionality problems, e.g. up/down, left/right, front/back, before/after</td>
<td>Spatial (vestibular)</td>
</tr>
<tr>
<td>Gross and fine motor coordination difficulties, e.g. learning to ride a bicycle, do buttons up, tie shoelaces, etc.</td>
<td>Vestibular, proprioceptive, visual and visual-motor integration</td>
</tr>
<tr>
<td>Hand–eye coordination difficulties, e.g. throwing or catching a ball, threading a needle, copying writing, and drawing</td>
<td>Primary or secondary visual problems: Primary problems resulting from eyesight; secondary resulting from oculomotor problems resulting from immaturity in the functioning of the CNS and from a cluster of immature primitive and postural reflexes</td>
</tr>
<tr>
<td>Poor manual dexterity particularly with <em>dysdiadochokinesis</em></td>
<td>Poor fine motor control – can be impaired as a result of retained palmar or oral reflexes</td>
</tr>
<tr>
<td>Speed and clarity of speech</td>
<td>Can result from many areas in the brain; motor aspects of speech can be affected by retained oral reflexes</td>
</tr>
</tbody>
</table>

*Dysdiadochokinesis – difficulty with rapid alternate movements; can affect the fingers, hands, feet, and the speech apparatus.*
## Table 1.10 Sensory processing problems in DCD

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Underlying mechanisms/systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyper- or hyposensitive in one or several sensory modalities</td>
<td>Poor integration between the sensory systems – there can be a number of causes for this; developmental history is important to identify specific underlying factors</td>
</tr>
<tr>
<td>Tactile hypersensitivity with a tendency to withdraw from contact, or hyposensitivity, which can result in poorly developed sense of body image and in difficulty recognizing shapes and textures</td>
<td>Can result from retained Moro or infant tactile reflexes</td>
</tr>
<tr>
<td>Vestibular problems resulting in poor balance, awareness of position in space, ability to make accurate spatial judgements, and sense of direction, speed and rhythm</td>
<td>Hyper- or hypovestibular; may be a primary or secondary dysfunction resulting from retained vestibular reflexes in the older child, and underdeveloped righting and equilibrium reactions resulting in a mismatch in the feedback loop from the proprioceptive system to the vestibular system</td>
</tr>
<tr>
<td>Auditory processing problems: discrimination, orientation, speed of processing, filtering out background noise</td>
<td>Developmental history of hearing impairment; unilateral hearing impairment, poorly developed auditory laterality, retained Moro reflex</td>
</tr>
<tr>
<td>Visual: control of eye movements, visual discrimination, spatial organization, form constancy, figure-ground effect, stimulus-bound effect</td>
<td>Primary refractive problems (eyesight); in the absence of refractive problems, oculomotor problems resulting in visual-perceptual problems are likely to stem from underlying postural dysfunction; specific visual-perceptual problems can result from damage to the right frontal lobe</td>
</tr>
</tbody>
</table>
ATTENTION DEFICIT DISORDER (ADD)

The essential feature of ADD is a persistent pattern of inattention that is more frequent and severe than is typically observed in individuals at a comparable level of development.

ADHD is now classified as a separate category from ADD, the additional criteria being a persistent pattern of inattention and hyperactivity/impulsivity that is more frequent and severe than typically observed in individuals at a comparable level of development. Symptoms that cause impairment must have been present before seven years of age, and the symptoms must be present in at least two settings (e.g., home and school). There must be clear evidence of interference with developmentally appropriate social, academic, or occupational functioning.

ADD and ADHD appear to involve many layers within the hierarchy of the brain from the cortex’s inability to focus and to maintain attention on tasks at the top, down to supporting systems involved in spatial organization, sensory integration, and auditory processing, which should support the higher cognitive functions.

The clinical criteria for ADD have been established as the presence of six or more of the following signs, which have persisted for at least six months and to a degree that is maladaptive and inconsistent with the developmental level:

- Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities;
- Often has difficulty sustaining attention or tasks or play activities;
- Often does not seem to listen when spoken to directly;
- Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace;
- Often has difficulty organizing tasks and activities;
- Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort;
- Often loses things necessary for tasks or activities;
- Is often easily distracted by extraneous stimuli;
- Is often forgetful in daily activities;
- Excessive daydreaming;
ATTENTION, BALANCE, AND COORDINATION

- Frequent staring;
- Lethargic;
- Confusion;
- Memory problems.

ADD is currently thought to be the result of a problem with the brain’s processing system, whereas ADHD is connected with the behavioural motor system.\(^{54}\)

**Symptoms of ADHD**

Six or more of the following must have persisted for more than six months to a degree that is inconsistent or maladaptive with the developmental level (Table 1.11):

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Physical mechanisms/systems involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often fidgets with hands or feet or squirms in seat</td>
<td>Immature postural control, inability to inhibit extraneous movement when at rest, may involve poor regulation of the neurotransmitter dopamine</td>
</tr>
<tr>
<td>Often leaves seat in class or in other situations in which it is inappropriate</td>
<td>Reticular activating system (RAS) involved in arousal and attention, frontal lobes (voluntary control of attention), temporal-parietal regions (involuntary attention(^{55}))</td>
</tr>
<tr>
<td>Often runs about, climbs excessively in situations in which it is inappropriate</td>
<td>Poor inhibition of movement or poor ability to maintain ‘stillness’, immature posture and motor skills, continuous need to provide stimulation to the vestibular system (hypoactive vestibular)</td>
</tr>
<tr>
<td>Often has difficulty playing or engaging in leisure activities quietly</td>
<td>Needs continuous sensory (auditory and vocal) feedback, seems unable to ‘internalize’ thoughts</td>
</tr>
<tr>
<td>Is often ‘on the go’ or acts as if ‘driven by a motor’</td>
<td>Unable to inhibit excess movement; needs constant motor and sensory feedback; needs to change down a gear (up the revs) to keep going; thought to be related to slower firing rate in the beta brainwaves; probably stems from a combination of hypovestibular functioning, immature motor skills, and hyperarousal (RAS) differences in the availability of neurotransmitters and abnormal brainwave variants</td>
</tr>
</tbody>
</table>
UNDERACHIEVEMENT

There also exists a group of children who do not qualify for assessment nor do they fit into any diagnostic category. These are usually children of above-average intelligence who are able to compensate for their underlying motor and postural problems to produce academic work that is commensurate with their chronological age or ‘good enough’ to meet the minimum requirements of standard educational assessments. These bright children are held back by their unrecognized motor and postural problems and tend to become ‘lost in the system’ because it is assumed they are performing reasonably well. Examination of this group for neurological dysfunction frequently reveals a profile of neurological immaturity which is masked by the processes of conscious compensation. When the underlying problems are identified and corrected, cognitive educational performance exceeds previous expectations.

THE SENSORY-MOTOR CONNECTION

All forms of life share the characteristic of motion, and movement is the vital ingredient of all forms of sensory perception and motor output. For example, the vestibular system (balance mechanism) comprises specialized receptors that respond to slow movements of the head. The sense of touch arises from the sensation of movement across fine hairs bedded into the dermis of the skin or of pressure applied to skin. The sense of hearing detects vibrations which travel at speeds from 20 to 20,000 Hz shortly after birth, narrowing down to a smaller range of frequencies in the first three to six years of life. What we perceive as sound is the ability of sound receptors to detect a specific range of motion frequencies. Similarly, at a simplistic level, vision is the response of specialized receptors in the eye which detect photons and waves of light travelling at faster frequencies still. While the senses keep the brain informed about momentary changes in the internal and external environments, each specializing in a different type of movement, it is the job of the CNS to conduct and to convert those impulses into meaningful sensations. Sensory experience and arousal are just the first phases of perception.
While the sensory systems provide information about the environment (feeling), integration of sensory experience takes place as a result of action or motor output in response to sensory signals (doing). Mastery of motor skills is supported by posture, and good postural control is the product of an integrated reflex system. In this way, the reflex system is the foundation on which higher postural- and motor-dependent skills are built. The significance of feedback from the motor system to the sensory systems is illustrated by the development of vision.

‘Nothing that is seen is understood by the sense of vision alone.’ In other words, what we experience through vision as adults is actually the product of years of multisensory experience – a compound sense – which has developed as a result of sight combined with moving, touching, and proprioceptive feedback from the muscles, tendons, and joints of the body in response to movement of the body through space. A newborn baby knows nothing of distance, speed, or depth. He or she can only focus at a distance of approximately 17 cm from the face, and the internal features of objects have little meaning until they have also been experienced through the other senses. The mother’s voice and the taste of her milk are more familiar to the neonate than how she looks in the first days of life, but the senses of smell, sound, and touch will all help the baby to recognize her visually within a few days.

I mentioned the infant rooting reflex earlier as a well-recognized example of a primitive reflex in the newborn. It also serves as an example of how one sensory system combined with movement experience helps to train another sense. The rooting reflex ensures that when the side of the neonate’s mouth is touched, the mouth opens, the head turns, and the baby will nuzzle against an object, searching for the breast (cats do something similar when they are hungry, brushing up against an object). Provided the baby receives satisfaction for its rooting attempts, within a few short weeks, the sight of the breast or bottle alone will be enough to elicit sucking movements.

It is also of interest to realize that a baby’s focusing distance at birth is approximately the same as the distance between the breast and its mother’s face. When a baby sucks, his eyes tend to converge at near distance, helping to train the eye
muscles to line up together to focus on the object at near distance and to ‘fuse’ the two separate objects seen by each into one clear image instead of two. In other words, the action of sucking assists in a process of oculomotor training which will later support the more complex visual-perceptual skills needed for reading, writing, and judging the speed of moving objects in a more advanced form. The eyes are but a window for the brain. In order to ‘make sense’ of what is seen, the brain must receive additional information from other senses combined with motor experience. A child’s reflex profile can provide additional information about motor competency in relation to chronological age and may help to explain why a child’s oculomotor skills, for example, are immature.

THEORIES OF MOTOR CONTROL

The brain comprises many separate entities which are all interlinked and interdependent. At birth, connections to the superficial layer of the cortex are only tenuously formed and in the first months and years of life, the developing nervous system forms millions of new connections between the nerve cells which provide a network of communication or neural circuitry of almost unimaginable complexity. It is on this neural circuitry – a circuitry that will adapt and change all through life – that behaviour and learning will be based. The layering of connections between motor areas is sometimes viewed as a hierarchy of systems, which involves multiple levels of control and is open to modification as a result of many influences – developmental, biochemical, and environmental. Reflex assessment provides one method of assessing maturity in hierarchical functioning.

During the process of normal development, functional direction and organized control of movement proceeds from the lowest regions of the brain (the brainstem) to the highest level of the CNS, the cortex. This process of corticalization is characterized by the emergence of behaviours organized at sequentially higher levels in the CNS with lower levels being recruited into the service of higher functions as maturation takes place. Each level of the nervous system can act upon other levels, higher and lower, in either direction, depending on the task. Reflex status can therefore provide
indications of integration in how the brain functions as well as point to specific receptors which may be involved in presenting symptoms. In order to gain an understanding of what primitive and postural reflexes can tell us, it is necessary to know what they do, both individually and collectively in early development, when they are inhibited, the interrelationship between inhibition and the development of new skills, and the possible effects if primitive reflexes fail to be inhibited or if postural reflexes do not develop fully. In Chapters 2–5, we will examine reflexes according to their main sensory receptors: the Moro reflex, a multisensory reflex; reflexes of position; reflexes of touch; and postural reflexes.

REFERENCES


