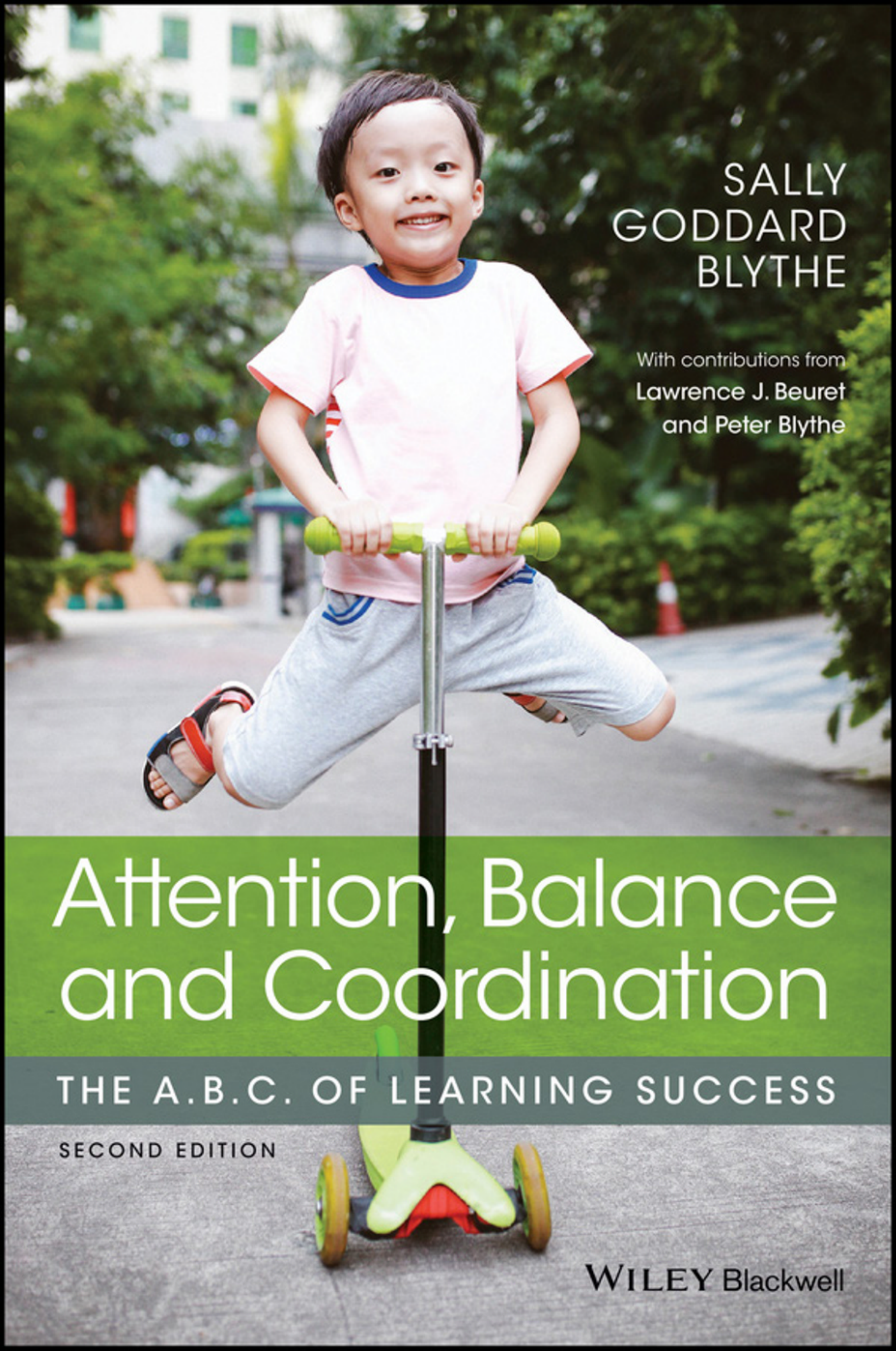

SALLY GODDARD BLYTHE

With contributions from Lawrence J. Beuret and Peter Blythe

Attention, Balance and Coordination

THE A.B.C. OF LEARNING SUCCESS

SECOND EDITION

WILEY Blackwell

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Valerie Scaramella-Nowinski

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About the Author

Sally Goddard Blythe, MSc, is a director of the Institute for Neuro-Physiological Psychology (INPP) in Chester, United Kingdom.

Sally Goddard Blythe has worked in the area of neurodevelopment since 1987, and is the author of several books and published papers on child development and neuromotor immaturity in specific learning difficulties. Her first book, *Reflexes, Learning and Behavior*, provided the basic information for many other professions throughout the world using reflex assessment. Her subsequent books—*The Well Balanced Child*, *What Babies and Children Really Need*, and *The Genius of Natural Childhood*—examine the importance of physical development and interaction with the environment for later learning success, health, well-being, and social integration.

Sally Goddard Blythe is also the author of *Assessing Neuromotor Readiness for Learning*—a screening test and daily physical movement program designed to be used in schools with a whole class of children over one academic year. This program has been the subject of published research[1] involving 810 children across various schools in the United Kingdom. The aim of the program is to enable teachers to identify children in the classroom who are at risk of under-achieving as a result of immature neuromotor skills (physical readiness for learning), and to implement a daily movement program to improve the physical foundations for learning. Sally Goddard Blythe is passionate about the need for better understanding of the issues involved, and about communication between professionals involved in education, medicine, and psychiatry. She is also the author of a screening test for clinicians and health practitioners.

Endnote

1 Goddard Blythe S. A., 2005. Releasing educational potential through movement. Child Care in Practice 11/4:415–432.

About the Contributors

Peter Blythe The late Peter Blythe, PhD, was formerly a senior lecturer in applied psychology/education at the College of Education in Lancashire. In 1969, he became aware that many children with average to above average intelligence who have specific learning difficulties in the classroom still had a cluster of primitive reflexes that should not be present above the first year of life and under-developed postural reflexes, which are necessary to support all aspects of education. These developmental "signposts" of maturity in the functioning of the central nervous system were connected to inability to demonstrate their intelligence in an acceptable academic way. In 1975, he established the Institute for Neuro-Physiological Psychology (INPP), where he developed the protocols of assessment and effective remedial intervention now known as "The INPP Method." He was the director of INPP until 2000. The INPP, located in Chester, United Kingdom, is the international training center for professionals seeking access to the INPP Method.

Lawrence J. Beuret Lawrence J. Beuret graduated from the Loyala Stritch School of Medicine in Chicago, Illinnois, United States. During a fellowship at the Mayo Clinic, he observed a high incidence of learning disabilities in the adolescent psychiatric population. Following two years as an emergency-room physician, he entered a private practice in the treatment of psychosomatic and post-traumatic stress disorders (PTSD). In 1985, he trained in Chester, United Kingdom, with Peter Blythe in the INPP treatment techniques for neurodevelopmental delay (NDD). In the course of practice, he has extended the diagnostic and treatment techniques of INPP to include pre-school ages, as well as adolescents and adults with reading and learning difficulties. He is currently active in developing courses for therapists in the recognition and treatment of subconscious aspects of PTSD. His medical practice is in the Chicago suburb of Palatine.

Valerie Scaramella-Nowinski Valerie Scaramella-Nowinski is committed to children, their health, learning, and development. She has worked as a clinician and researcher regarding pediatric brain behavior development for more than 35 years.

Her doctoral research was titled "Systems Analysis: A Neuropsychological Investigation of the Psychological Structure and Cerebral Organization of Human Mental Processes." Nowinski's clinical research involves: electrophysiological dysrhythmias associated with neurodevelopmental disorders; eye movement related to brain behavior development, especially literacy development; and neurodevelopment of intelligence and learning. Throughout her professional career, she has been deeply involved in developing neurosystems biology understanding regarding human development and learning, especially in the pediatric population.

Nowinski is the founder of the Pediatric Neuropsychology Diagnostic Center, Orland Park, Illinois, United States. The center houses three specialty programs: Brain Injury Program, Autism Spectrum Program, and Neurodevelopmental Disorders/Attention and Learning Disorders Program. These diagnostic and training programs incorporate an interdisciplinary team of pediatric specialists, including neuroscientists, educators, and speech, language, movement, child development, and learning specialists. Bridging neuroscience with education is a primary focus at the center.

She and her team have developed brain training and education programs for thousands of children. The team consults for multiple school districts, hospitals, health and allied health specialists, and child development programs.

In 2003, Nowinski and her family founded the Neuropsychology C.H.I.L.D. (Child Health Initiative for Learning and Development) Foundation, non-profit 501 (c)(3). The mission of the foundation is to "promote public awareness of current neuroscience and education research and clinical work related to child development and learning."

1

Windows on the Brain

1.1 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 behavior 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.

> Reflexes *will be described in detail in subsequent chapters.*

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 behavior. 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 behavior, developing protocols for the assessment

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Second Edition. Sally Goddard Blythe.

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 past 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 program 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 older children 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 behavioral 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.

1.2 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, pediatrician, and health visitor) to education at the time of school admission, a child's developmental readiness in terms of *physical* development is not assessed as a matter of routine. Once a child enters formal education on reaching five years of age in the UK, assessment of physical development takes place only if medical problems arise. Assessment within the school system tends to focus on educational problems or visible symptoms rather than investigation of underlying causes.

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 programs to correct the underlying dysfunctions. These methods of assessment, which involve examining the neurodevelopmental level of the child and the subsequent physical programs of remedial intervention, are now known as the INPP Method of Developmental Training.

By the very nature, symptoms of specific learning difficulties tend to cross diagnostic boundaries, with different categories sharing a number of symptoms in common (comorbidity). 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 neurodevelopmental delay.

1.3 What Is Neuromotor Immaturity?

Neuromotor functioning provides one indication of maturity in the functioning of the CNS. It is also linked to functioning of the vestibular, proprioceptive, and postural systems, which cooperatively provide a stable platform for centers involved in oculomotor functioning and subsequently visual perception. Individuals with neuromotor immaturity (NMI) frequently experience difficulties with related skills such as balance, coordination, and visual perception, which can affect behavior and educational performance in children, and manifest as chronic anxiety and emotional sensibility in adults.

One method of identifying signs of NMI is through the use of standard tests to assess retention of primitive reflexes, development of postural reactions, and other tests for "soft signs" of neurological dysfunction. Soft signs, which have previously been dismissed as being too generalized to be useful diagnostic purposes are minor neurological signs, which suggest nonspecific cerebral dysfunction.

The presence or absence of primitive reflexes at key stages in development provide acknowledged signposts of maturity in the functioning of the CNS. Primitive reflexes emerge in utero, are present in the full-term neonate, and are inhibited in the first six months of postnatal life when connections to higher cortical centers and frontal areas develop. Primitive reflexes are also suppressed and integrated into more mature patterns of behavior in the course of normal development as postural reactions and muscle tone develop. Postural reflexes can take up to three and a half years to mature.

Primitive reflexes are retained in certain pathological conditions, such as cerebral palsy. In cerebral palsy, retention of reflexes occurs as a result of damage to the brain or abnormal development which may have occurred prenatally, at birth, or postnatally [1–7]. Damage to the immature brain interferes with the normal process of maturation in a predictable, orderly, developmental sequence resulting in lack of inhibition, demonstrated by prolonged retention of the primitive undifferentiated patterns of movement control characteristic of infancy, accompanied by abnormal muscle tone, development of postural control, impaired patterns of movement, and delayed motor development. Primitive reflexes also re-emerge in degenerative conditions such as multiple sclerosis and Alzheimer's disease, when demyelination results in deterioration of postural reactions, and primitive reflexes are disinhibited. For many years it was assumed that retention of primitive reflexes could not exist to a lesser degree in the absence of identified pathology and therefore primitive reflexes have generally not been the subject of investigation in children with less severe motor delays or children who simply present with signs of a specific learning difficulty.

The term *Neuromotor Immaturity (NMI)* as used by INPP describes the continued presence of a cluster of primitive reflexes in a child above six months of age together with absent or underdeveloped postural reactions above the age of three and a half years. NMI influences and also provides a reflection of maturity in the development and control of posture, balance, and motor skills.

> Neuromotor immaturity (formerly neurodevelopmental 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 reactions above the age of three and a half years.*

1.4 What Is the Connection between NMI 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, which is also a motor skill. Sitting still and paying attention require postural control, balance, and orientation, in addition to the involvement of cortical centers implicated in the maintenance of attention; aspects of mathematics require spatial skills and communication 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.

The vestibular system *is a system responsible for maintaining balance, posture, and the body's orientation in space. This system also regulates locomotion and other movements and keeps objects in visual focus as the body moves. The* cerebellum *is the control center for balance and movement coordination. As part of the nervous system, it receives two types of input: one locating the body's position in space and the other indicating whether the muscle is contracted or relaxed. Based on this information, and depending on the desired action (move forward, grasp, etc.), the cerebellum triggers, adjusts, or stops a movement.*

Spatial skills develop 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 judgments 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 [8]." 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 [9]. The cerebellum is also linked to the ability to sequence not only motor tasks but also associated cognitive processes [10].

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 centers 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 centers to support and to feed information to the cortex.

Bilateral integration *is the ability to carry out movements on one side of the body independently of the other side and the ability to coordinate both sides of the body in many different combinations.*

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 act as barriers to 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 [11]." 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 [12]."

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 centers in the brainstem, midbrain, cerebellum, and basal ganglia in the service of the cortex.

1.5 Primitive and Postural Reflexes—the Medical Model

It is medically accepted that abnormal reflexes can persist as a direct result of pathology such as the previously mentioned example of cerebral palsy when damage to higher brain centers 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 fibers in the hardened patches to break up and become absorbed, leaving the nerve fibers 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 centers. 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 in the form of primitive, protective, survival mechanisms.

The transition from primitive to postural reflex in the first year(s) of life is a gradual one. It not only 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. Neurons that fire together repeatedly, wire together. As connections between higher and lower centers become established, primitive reflexes are inhibited and integrated to make way for more advanced systems of voluntary movement and postural control.

Structural development of the nervous system takes places as a result of maturation *and interaction with the environment. Every species begins life with a common tool kit of genes involved in bodybuilding, but the development of the nervous system in each individual is the product of using the same genes in different ways.*

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 supporting 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 [13]."

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 centers. In this way, primitive reflexes continue to remain available to fulfill 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 [14–22].

The *effects* of retained primitive reflexes and underdeveloped postural reflexes in older children are well documented [23–26]. It is also recognized that aberrant reflexes can affect higher cortical functioning particularly in the area of education [24, 27, 28], but even after 30 years of publication of this research, 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 [29].

1.6 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); and
- measure change (clinical evaluation).

1.7 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 cognitive processes [30]." 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; and
- 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 (comorbidity). When common areas of 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 "gray area" that existed between the disciplines of medicine, psychology, and education by listing a cluster of symptoms for which there was no clear pathology.

In many cases, when comorbidity 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 behavior in a number of ways. *A*ttention, *b*alance, and *c*oordination are the first *ABC* on which *d*evelopmental readiness for *e*ducation is built.

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:
A = Attention
B = Balance
C = Coordination = Developmental readiness for educational achievement.

1.8 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 significant underlying factors in many specific learning difficulties, it is necessary to examine 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).

Each of the specific learning difficulties mentioned before involves impairment in the perception, organization, or execution of controlled movement: attention deficit hyperactivity disorder (ADHD), for

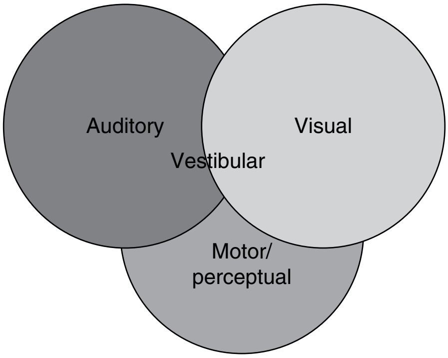

Figure 1.1 Comorbidity of symptoms in specific learning difficulties: dyslexia.

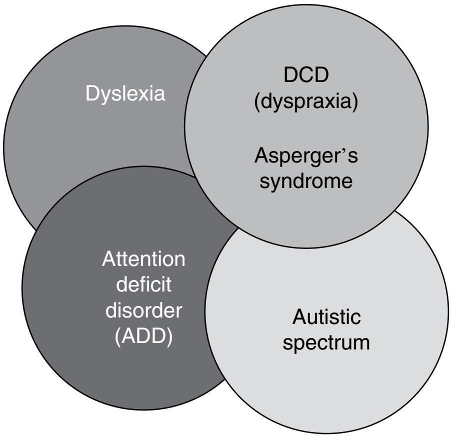

Figure 1.2 Comorbidity in underlying problems in dyslexia, DCD, ADD, and in some aspects of autistic spectrum disorders.

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.

1.9 Dyslexia—Signs and Symptoms

1.9.1 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 [31]." In 2009, this definition was expanded and described by Rose in a report compiled by a group of experts for the Secretary of State for children and families in the UK [32] as, "a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling."

- Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory, and verbal processing speed.
- Dyslexia occurs across the range of intellectual abilities.
- It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points.
- Co-occurring difficulties may be seen in aspects of language, motor co-ordination, mental calculation, concentration, and personal organization, but these are not, by themselves, markers of dyslexia.

A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention.

1.9.2 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 [33]. Performance in these areas is dependent upon the maturity of the reflex system which underlies motor learning, vestibular functioning, and kinesthetic integration.

1.9.3 Neurological Factors in Dyslexia

Ever since dyslexia was first identified, it has been hypothesized that structural abnormalities in the brain may underlie the disorder.

Postmortem 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 [34–36].

Over the past 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 [37–40]
2) Immature motor skills [41–45]
3) Auditory processing problems [46, 47] and the phonological deficit theory [48–52]
4) Abnormal processing of visual information [53–55]

In 1996, Fawcett and Nicolson [39] 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 automisation, 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 [56]—an area of the brain involved in processing and filtering sensory information—and genetic susceptibility for developmental dyslexia [57].

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 centers 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.

> Corpus callosum—*the bundle of nerve fibers which allow for the exchange of information between the two cerebral hemispheres.*

The automization of skills depends upon 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 systems. Postural reflexes are important for maintenance of posture and the execution of controlled movements in cooperation with other centers such as the cerebellum, basal ganglia, and motor cortex.

Features of dyslexia are as follows:

- 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, and multiplication tables
- Marginally late developmental milestones, such as crawling (may have omitted crawling stage), walking, talking, and reading

Children with dyslexia have difficulty with the following:

- Ambi- or cross-laterality
- Differentiation 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 (see Tables 1.1–1.6)

1.9.4 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).

1.10 Developmental Coordination Disorder

Dyspraxia describes difficulty with praxis, praxis being a derivation of the Greek word for "action." Formerly described as the clumsy child syndrome, the term dyspraxia has been replaced by DCD. DCD is defined by the *Diagnostic Statistical Manual of Mental Disorders 5* (DSM5) as a condition in which,

> A) The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports.
>
> B) The motor skills in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts

Table 1.1 Physical symptoms in dyslexia

Motor skills	Symptom	Subcortical mechanisms/ systems involved
Gross motor skills	Hopping, skipping, and forward rolls	Balance, sequencing of movements (cerebellum), and upper/lower body integration
	Catching, throwing, and kicking a ball	Hand/eye, eye/foot coordination
	Clumsy when going upstairs	Left/right, upper-, and lower-body coordination
	Marginally late developmental milestones, for example, crawling, walking, talking, and reading	Balance, posture, bilateral integration
	Learning to ride a bicycle	Vestibular, postural, and bilateral integration
	Learning to swim	Poor upper- and lower-body and left/right coordination
	Coordination at gym, climbing a rope, working with an apparatus	Vestibular, postural, hypotonic, upper- and lower-body integration
Fine motor skills	Difficulty using equipment, for example, scissors, cutlery	Fine motor skills, dysdiadochokinesis (cerebellum and motor cortex)
	Immature or awkward pencil grip	Retained reflexes affecting manual dexterity
	Difficulty learning to tie shoelaces, do buttons up, and so on.	Fine motor skills, directionality (vestibular), left/ right integration

academic/school productivity, prevocational and vocational activities, leisure and play.

C) Onset of symptoms is in the early developmental period.

D) The motor skills deficit are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder). [58]

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

Table 1.2 Directionality problems in dyslexia

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

Table 1.3 Speech and language symptoms in dyslexia

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

Table 1.4 Sequencing problems in dyslexia

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

Table 1.5 Visual symptoms in dyslexia

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

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 color 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

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

Table 1.7 Phobic disorders in dyslexia

Symptom	Underlying mechanisms/systems
Fear of the dark, heights, new places	Poor orientation in the absence of visual points of reference (vestibular/proprioceptive)
Fear/avoidance of motor-related activities	Immature coordination and postural control
Mood disturbances	Performance anxiety, frustration, orientation problems, biochemical, hormonal
Obsessive–compulsive tendencies	Increased metabolic activity in left orbital gyrus [59] deficiency in availability of the neurotransmitter serotonin [60], heightened glucose metabolism in the frontal lobes

Table 1.8 Psychosomatic symptoms in dyslexia

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

developed a 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 behavior. 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).

Table 1.9 Motor coordination symptoms in DCD

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

Dysdiadochokinesis—*difficulty with rapid alternate movements; can affect the fingers, hands, feet, and the speech apparatus.*

Table 1.10 Sensory processing problems in DCD

Symptoms	Underlying mechanisms/systems
Hyper- or hyposensitive in one or several sensory modalities	Poor integration between the sensory systems—there can be a number of causes for this; developmental history is important to identify specific underlying factors
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	Can result from retained Moro or infant tactile reflexes
Vestibular problems resulting in poor balance, awareness of position in space, ability to make accurate spatial judgments, and sense of direction, speed and rhythm	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
Auditory processing problems: discrimination, orientation, speed of processing, filtering out background noise	Developmental history of hearing impairment; unilateral hearing impairment, poorly developed auditory laterality, retained Moro reflex
Visual: control of eye movements, visual discrimination, spatial organization, form constancy, figure-ground effect, stimulus-bound effect	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

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

1.10.1 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.

1.11 Attention Deficit Disorder

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. Inattention manifests itself as wandering off task, lacking persistence, having difficulty sustaining focus and being disorganized. These symptoms are not due to defiance or lack of comprehension [58].

ADHD is now classified as a separate category from ADD, the additional criteria being a persistent pattern of inattention with excessive motor activity when it is not appropriate, or excessive fidgeting, tapping or talkativeness and impulsivity that is more frequent and severe than typically observed in individuals at a comparable level of development. Impulsivity refers to hasty actions that occur in the moment without forethought and have high potential for harm for the individual. Symptoms of ADHD are evident before 12 years of age and 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
- 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 behavioral motor system [61].

1.11.1 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 1.11 Criteria for ADHD

Symptoms	Physical mechanisms/systems involved
Often fidgets with hands or feet or squirms in seat	Immature postural control, inability to inhibit extraneous movement when at rest, may involve poor regulation of the neurotransmitter dopamine
Often leaves seat in class or in other situations in which it is inappropriate	Reticular activating system (RAS) involved in arousal and attention, frontal lobes (voluntary control of attention), temporal-parietal regions (involuntary attention [62])
Often runs about, climbs excessively in situations in which it is inappropriate	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)
Often has difficulty playing or engaging in leisure activities quietly	Needs continuous sensory (auditory and vocal) feedback, seems unable to "internalize" thoughts
Is often "on the go" or acts as if "driven by a motor"	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

1.12 Underachievement

There also exists a group of children who do not qualify for formal 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.

1.13 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 20000 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 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 acts as the foundation on which higher postural and motor-dependent skills are built. The sense of vision provides one example of how closely sensory and motor functioning are intertwined.

"Nothing that is seen is understood by the sense of vision alone" [63]. In other words, what we experience through vision as adults is actually the product of years of *multi*sensory 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 a 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, her 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.

1.14 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 behavior 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 behaviors 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 reactions 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.

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2

The Significance of Primitive and Postural Reflexes

Reflexes were described as early as the seventeenth century by physician Thomas Willis when he used the term "motus reflexus" and "reflexion" to describe how impulses of spirits in the nerves to the central nervous system (CNS) could be "reflected" back to the muscles. He described the automatic action as being similar to light bouncing off a mirror.

There are many different types of reflexes. Although they differ in many respects, they share the common property of being stereotyped and constant "because the same stimulus always gives the same kind of response [1]." Some reflexes like the blink reflex are simple; others like the swallowing reflex are more complex, involving the cooperation of many structures. Some reflexes only involve lower parts of the CNS such as the spinal cord and the brainstem, whereas others, such as the oculo-head righting reflexes (OHRRs), involve higher parts of the nervous system, including the cortex. "Many of the tasks of the nervous system are carried out reflexively—that is, independent of our consciousness. This, of course, frees the higher levels of the brain from handling numerous trivial everyday tasks [1]." Although reflexes largely operate independently of will, some, such as reflexes for emptying the bladder and rectum, can be suppressed voluntarily; others, such as reflexes involved in the control or *visceral* functions, take place without any conscious awareness. Primitive and postural reflexes provide useful tools with which to assess the CNS, because they are *developmental* in terms of when they should be active and *hierarchical* in terms of the level of the nervous system involved.

> *The* viscera *are the soft internal organs of the body, including the lungs, the heart, and the organs of the digestive system. Visceral functions are functions involving these systems.*

Attention, Balance and Coordination: The A.B.C. of Learning Success,
Second Edition. Sally Goddard Blythe.

2.1 What Are Primitive and Postural Reflexes?

Primitive reflexes develop in the womb, are present at birth in the full-term neonate, and are inhibited by higher centers in the developing brain in the first six months of postnatal life.

Postural reflexes emerge after birth and take up to three and a half years to be fully developed. By the time a child reaches school age, in theory at least, the postural reflexes should be developed, and no signs of continued primitive reflex activity should be evident.

2.2 What Do Primitive and Postural Reflexes Tell Us?

1) Assessment of primitive and postural reflexes at key stages in development can be used to identify signs of *immaturity* in the functioning of the nervous system (identification). Many of the primitive reflexes are tested as a matter of routine at birth, as part of the neonatal neurological examination, but are rarely carried out later in development unless a neurological problem is suspected.
2) Reflex tests can be used again at later stages of development on school-aged children, but when these are used on older children, the examiner looks for signs of inappropriately *retained* primitive reflexes and *under-developed* postural reflexes (assessment).
3) Reflex evaluation can also provide indications of the type and developmental level of intervention needed to integrate abnormal reflexes (remediation).
4) Reflex tests can also be used during and after an intervention program to measure the changes that have occurred as a result of remedial intervention (evaluation).

Collectively, abnormality in the profile of these two groups of reflexes provides indications of neurological dysfunction or neurological immaturity.

In order to understand how reflex testing can be used in these ways, it is necessary to examine reflex development in the broader context of general development and also individually in more specific detail.

2.3 The Developing Brain

The nervous system begins to develop very early in embryonic life. In fact, just three weeks after fertilization, the ectoderm, the outer layer of the three sheets of cells that make up the embryo at this very early stage,

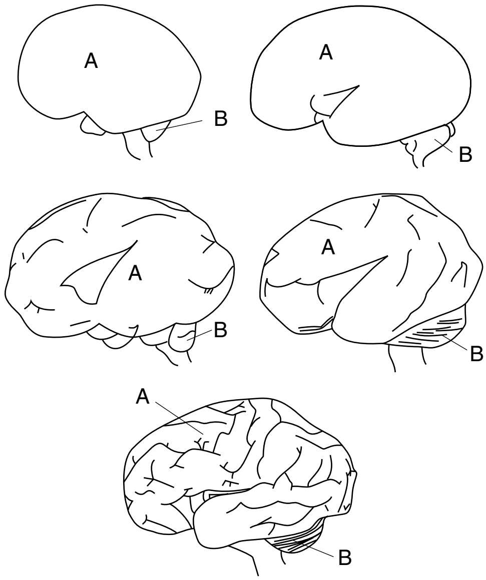

Figure 2.1 The maturing brain from four to eight months' gestation. (A) Cerebral hemisphere (B) cerebellum.

thickens to form a neural plate. The neural plate then develops a neural groove; neural crest cells form, and the neural groove deepens to form the neural folds. One week later, the neural folds fuse to form a neural tube, which dilates to form the beginning of the forebrain, midbrain, and hindbrain, while the remainder of the tube elongates to form what will become the spinal cord. At five weeks, the forebrain and hindbrain (vesicles) divide, and the cerebral hemispheres begin to expand. At six weeks, the thalamus, which will later act as a central "relay" and processing station for all sensory information with the exception of smell, and the cerebellum or "little brain," which will be involved in the coordination of movement and automization of motor output, appear (Figure 2.1).

At eight weeks, the brain starts to take on a human appearance and the first reflex arc becomes functional. Reflex actions, described by Sherrington [2] in the early 1900s, are a functional unit comprising an effector (sense organ), conductor (at least two or more nerve cells), and a receptor. These components make up the reflex arc:

- A *receptor*—which registers the stimulus and translates the stimulus to *action potentials*;
- An *afferent link*, comprising a sensory neuron, which conducts the action potential to the nervous system;
- A *reflex center* in which the signals from the receptor may be modified (increased or decreased) by signals from other receptors and from parts of the CNS before signals are passed on to *effectors*;

- An *efferent link* comprising neurons passing *out* of the CNS, which conducts action potentials to the organ producing the response;
- An *effector*, which is the responding muscle(s) or glands.

Action potential—*the change in membrane potential occurring in nerve, muscle, or other excitable tissue when excitation occurs.*

One of the functions of the *receptor* is to lower the threshold for a particular type of stimulus while raising the threshold for all others. In this way, reflexes are responses to specific types of stimulation. Because they are largely carried out below the level of conscious awareness, reflexes provide information about the integrity of the nervous system free from interference from the psyche.

2.4 The Emergence of Spinal Reflexes

Reflexes are just one type of movement, which emerge during life in the womb. The earliest reflex-type response appears at five to seven and a half weeks after conception in response to tactile stimulation of the area which will eventually form the upper lip. Stroking with a fine hair elicits withdrawal of the head, neck, and trunk [3, 4]. Over the course of the succeeding weeks, tactile sensitivity and reactivity spreads from the upper lip in an outward spiral pattern to encompass more of the area around the mouth, the palms of the hands, and the soles of the feet until eventually, by 13–14 weeks postconception, the whole body surface will become responsive to touch. The initial reaction to this type of stimulation is one of withdrawal and is an example of a *spinal reflex*.

Spinal reflexes function at the base of the hierarchical control system. They are somatic reflexes mediated by the spinal cord, but they can involve higher brain centers. When a spinal reflex is elicited, the message is simultaneously sent to the spinal cord and the brain, but the reflex triggers the response from the spinal level without waiting for higher brain analysis. Withdrawal reflexes such as the *flexor withdrawal reflex* and the *crossed extensor reflex* are other examples of spinal reflexes.

2.5 Reflexes Mediated at the Spinal Level

2.5.1 Flexor Withdrawal Reflex

The flexor withdrawal reflex is sometimes referred to as the "flight reflex," the defense reflex, or the negative supporting reaction. Reflex movement