

A young child with dark hair, wearing a light pink t-shirt and grey shorts, is smiling while riding a green and black scooter on a paved path. The background shows lush green trees and a building with green windows.

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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The A.B.C. of Learning Success

Second Edition

Sally Goddard Blythe

*With contributions from
Lawrence J. Beuret, Peter Blythe, and
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 research¹ 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, Illinois, 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

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 pin-head-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 place 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. Attention, balance, and coordination are the first *ABC* on which developmental readiness for education 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

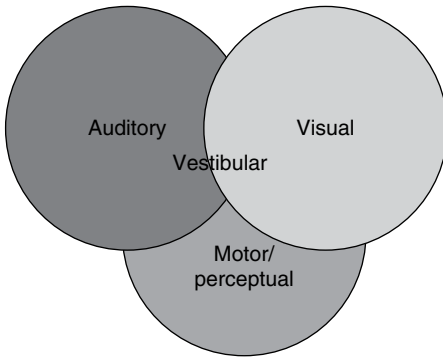


Figure 1.1 Comorbidity of symptoms in specific learning difficulties: dyslexia.

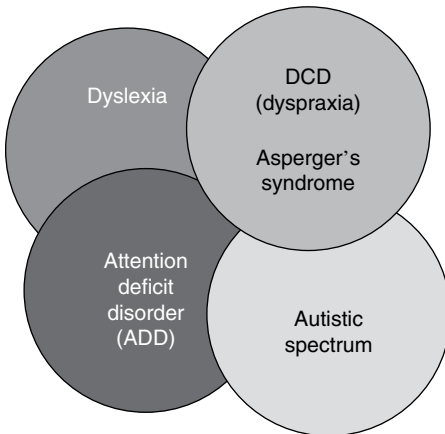


Figure 1.2 Comorbidity in underlying problems in dyslexia, DCD, ADD, and in some aspects of autistic spectrum disorders.

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
Fine motor skills	Coordination at gym, climbing a rope, working with an apparatus	Vestibular, postural, hypotonic, upper- and lower-body integration
	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 <i>dysdiadochokinesis</i>	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