1 Introduction

1.1 OVERVIEW

A significant percentage of children in mainstream schools has been found to have immature motor skills and postural instability.[1] Such neuromotor immaturity is often rooted in the continued presence of a cluster of primitive reflexes (normally present in infants up to six months of age, and then replaced over time by postural reactions). Research has shown that there is a direct correlation between immature motor skills and educational achievement. With proper guidance and instruction, teachers and other professionals can be trained to screen for signs of such delay, so that appropriate referrals can be made or physical intervention programmes introduced. This book provides all the tools and guidance needed to identify children with such immaturity, implement a physical programme if appropriate and evaluate outcomes.

There are many motor training and movement programmes available, but the model developed by The Institute for Neuro-Physiological Psychology (INPP) described in this book is unique in having been evaluated in practice and offering a means of assessing neuromotor status in the pre-school and school-aged child both at the beginning and end of intervention.

The book is organized in three sections:

1. The first section offers a series of screening tests for children aged 4–7 years to assess the presence of three reflexes, control of static balance, coordination, visual perception and visual-motor integration.
2. The second section provides a similar series of screening tests for children from seven years of age and above.
3. The third section details a complete developmental movement programme designed to be used with whole classes or smaller groups of children over the course of one academic year.

This book may be supported and enhanced by INPP video training materials and score sheets, available for download purchase from www.accessnmr.inpp.org.uk.

Assessing Neuromotor Readiness for Learning: The INPP Developmental Screening Test and School Intervention Programme, First Edition. Sally Goddard Blythe.

1.2 RATIONALE FOR SCREENING AND REMEDIATION OF NEUROMOTOR IMMATURITY

The INPP programme for schools is based on a clinical programme developed at The Institute for Neuro-Physiological Psychology (INPP); it has been used since the 1970s. In 1996, key tests were selected from the INPP full diagnostic assessment and clinical programme and adapted by the author for use with larger groups of children in a school setting.

This adapted series of screening tests is intended to be used by teachers, doctors and other trained professionals involved in child development and education *as a screening tool only*. It will not provide sufficient detailed information to justify a diagnosis, nor is it intended to replace standard neurological examinations, psychological or educational assessments usually carried out by trained psychologists, remedial specialists, medical and other non-medical professionals. It will, however, provide tools which enable a teacher to identify children who are under-achieving as a result of immature neuromotor skills and who are likely to benefit from the INPP programmes or other physical remedial programmes.

The INPP developmental movement programme comprises a series of daily exercises, based on movements normally made by the developing child in the first year of life. These movements must be carried out every day under teacher supervision. One of the major differences between the INPP Programme and many other programmes designed to improve coordination and balance, is that the INPP exercises take children back to the very *beginning* of balance training and postural development.

1.3 WHAT IS INPP?

The Institute for Neuro-Physiological Psychology (INPP) was established in 1975 by Psychologist Peter Blythe PhD with several aims in mind:

1. To research into the effects of immaturity in the functioning of the central nervous system (CNS) in children with specific learning difficulties (and adults suffering from anxiety states, agoraphobia and panic disorder).
2. To develop reliable methods of assessing CNS maturity.
3. To devise effective remedial intervention programmes.

Children seen at the INPP are examined on an individual basis using a series of standard medical tests to assess a range of physical abilities:

- gross muscle coordination and balance;
- patterns of motor development;
- cerebellar involvement;
- dysdiadochokinesia (ability to carry out rapid alternate movements);
- aberrant primitive and postural reflexes;
- oculomotor functioning (control of eye movements);
- visual perception
- visual motor integration (VMI)
- audiometric examination and dichotic listening.

The diagnostic assessment findings provide the basis for an individual regime of physical exercises which the child carries out every day at home under parental supervision. The exercises take between five and ten minutes a day over a period of approximately twelve months. The child is reviewed at six to eight weekly intervals to assess progress and adjust the exercises accordingly.

One of the problems with the INPP clinical programme has always been that it involves detailed assessment on a one-to-one basis, is costly in terms of professional time and can, therefore, only reach a relatively small number of the children who would benefit from this type of assessment and intervention. It was to overcome this problem that, in 1996, the author selected a reduced number of tests from the INPP diagnostic assessment and compiled the shortened screening tests in this book, which have been designed to be used as a *screening device* by teachers and other professionals involved in education and child development, to enable them to identify children with signs of neuromotor immaturity.[2]

1.4 THE INPP DEVELOPMENTAL MOVEMENT PROGRAMME FOR SCHOOLS

As part of the same package, the author also devised a unique developmental movement programme for use in schools. The concept behind the combined screening tests and developmental programme was that teachers could be trained in a one day course how to administer the screening tests, enabling them to identify children with signs of neuromotor immaturity in the classroom and implement effective intervention.

The Developmental Movement Programme is designed to be used with a whole class of children or smaller selected groups for ten minutes a day, every school day over the course of one academic year. Teachers do not select specific exercises for individual children but use the developmental movements in sequence, progressing according to the abilities of the class with the slowest child setting the pace.

This programme has been widely used in individual schools throughout the United Kingdom, in other European countries and as far afield as South Africa and Mexico. Research carried out on the screening tests and developmental movement programme has consistently shown that:

1. Neuromotor immaturity is a factor amongst children in mainstream schools.
2. There is a link between neuromotor immaturity and lower educational performance.
3. The INPP Developmental Movement Programme is effective in reducing markers of neuromotor immaturity.
4. When clear signs of neuromotor immaturity ($>25\%$) *and* educational under-achievement coexist, children who followed the INPP developmental movement programme showed greater improvements in measures of non-verbal cognitive performance and reading.[3]
5. Small group studies have indicated that children who were under-achieving by more than a year in reading and who had clear signs of neuromotor immaturity ($>50\%$), made significantly increased gains in reading at the end of the year having followed the INPP Developmental Movement Programme.[4]

1.5 WHAT IS NEUROMOTOR IMMATURITY?

Neuromotor performance describes a complex functional behaviour which results from activation of the central and peripheral nervous systems and involves motor structures which operate through the musculo-skeletal system involving multiple inputs from the individual's internal and external environment. The systems and structures responsible for movement within an individual are constantly evolving throughout the developmental process, but at certain stages in development a child is expected to have attained a certain level of neuromotor performance. Motor milestones and motor performance provide outward signs of functional neuromotor maturity.

Neuromotor immaturity describes the retention of immature patterns of movement control. These may occur as a result of classical neurological signs (pathology) or be reflective of a functional or developmental delay in the pathways involved. The INPP screening tests are aimed at identifying various 'soft signs'* of neurological dysfunction together with the presence of three primitive reflexes in the school-aged population. These tests do not point to causation, neither do they predict learning outcomes in individuals, but they can help to identify the presence of obstacles to educational achievement. Furthermore, in many cases these obstacles can be removed with the use of a specific developmental movement programme.

1.6 WHAT IS THE SIGNIFICANCE OF PRIMITIVE REFLEXES TO EDUCATION?

Primitive reflexes are included in the INPP screening tests because the presence of primitive reflexes at key stages in development provides acknowledged signposts of maturity in the functioning of the central nervous system. While doctors, midwives and health visitors are familiar with assessment of the primitive reflexes at birth, and tests for primitive reflexes are repeated at developmental check-ups in the first six months of postnatal life, if development appears to be progressing normally in the first year then these tests are not repeated in the pre-school or school-aged child

'While motor milestones – the neurodevelopmental functional end point of the transitioning of the immature and mature primitive reflexes into volitional activity – have been highlighted in predicting future motor function, the primitive reflexes represent the earliest neurodevelopmental markers available for study. By paediatricians becoming familiar with their quantitative and qualitative aspects, coupled with the time of their appearance and suppression, they will have this neuromotor tool available for the early detection of a significant motor handicap. Primitive reflexes have been highlighted since they are available at birth to be clinically evaluated and followed during sequential office visits during the first six months of life, the time during which infants are more closely followed at office visits. Delay or deviancy (non-sequential appearance) of motor milestones are preceded by an exaggeration or delayed suppression of the primitive reflexes'.[5]

* Soft sign – a mild or slight neurologic abnormality that does not provide specific information about cause or locus of the problem.

1.7 WHAT ARE PRIMITIVE REFLEXES?

Primitive reflexes are a group of reflexes which develop during life in the womb, are fully developed at birth in the full term baby (40 weeks) and are gradually inhibited and transformed into more mature patterns and postural abilities during the first six months of postnatal life. Only one of the primitive reflexes, the Tonic Labyrinthine Reflex (TLR), can remain in a modified form up to three and a half years of age.

Inhibition and transformation occur primarily as a result of maturation within the developing central nervous system. Primitive reflexes never entirely disappear but become inhibited as 'higher' centres in the brain mature in the first months of life. Primitive reflexes can remain active if there has been damage to higher centres in early life, such as cerebral palsy, or if there is accident or damage to higher brain centres in later life, for example after a stroke, head injury or in degenerative diseases of the central nervous system, such as multiple sclerosis or Alzheimer's disease. According to medical theory, primitive reflexes should not remain active in the general population beyond six months of age, and if elicited beyond this age are usually considered to be indicative of underlying pathology.

However, there is an increasing body of evidence which suggests that *traces* of primitive reflexes (residual reflexes) can remain active in the general population in the absence of identified pathology.[1,3,6–9] These individuals often do not fit into a particular diagnostic category, but the development of certain motor functions necessary to support learning fail to remain commensurate with chronological age. Residual presence of primitive reflexes in children above the age of six months can, therefore, provide indications of neuromotor immaturity, which acts as a barrier to learning.

Assessment of primitive reflexes beyond the first six months of life provides the clinician or educator with tools with which to:

1. Identify signs of neuromotor immaturity (Identification).
2. Assess the type and level of intervention that is appropriate for the child (Intervention/Remediation).
3. Measure change in reflex status before and after intervention (Evaluation).

1.8 WHAT IS THE SIGNIFICANCE OF NEUROMOTOR MATURITY TO EDUCATION?

A longitudinal study tracking the progress of nearly fifteen thousand children who were born in the United Kingdom between 2000 and 2001[10] released findings in February 2010; it showed that children who failed at nine months to reach four key milestones in gross motor development relating to sitting unaided, crawling, standing and taking their first steps were found to be five points behind on average cognitive ability tests taken at five years of age compared to those who passed the milestones. 'Delay in gross and fine motor development in a child's first year, was significantly associated with cognitive development and behavioural adjustment at five'.[11]

Readiness for school requires much more than a child simply reaching the chronological age for school entry. To perform well in an educational environment, a child needs to be able to:

sit still, focus attention on one task without being distracted by irrelevant environmental stimuli, hold and manipulate a writing instrument, and to control the eye movements necessary to maintain a stable image on the page, follow a line of print without the eyes 'jumping' or losing their place and adjust visual focus between different distances at speed. These are physical abilities, which are linked to the development and maturation of motor skills and postural control. Growth and physical development are as important to education as they are to the field of developmental medicine but have been largely ignored by the educational system since the routine developmental testing of all children was phased out (in the United Kingdom) in the 1980s.

The disappearance of developmental testing of every child at the time of school entry was the result of two changes in the administration of the whole area of special needs in education in the United Kingdom. First responsibility for the management of special needs was handed over from the Department of Health to the then Department of Education and Science. This meant that responsibility for investigating the causes of special needs transferred from the domain of medicine to that of the educational psychologist and teachers trained in special educational needs. Under this arrangement, although the testing of children's *cognitive* abilities was secure, the testing of children's physical developmental status was no longer carried out as a matter of course. Second in the words of a retired paediatrician 'we entered an era of evidence-based medicine when it became necessary to provide a proven remedy for any problems that were detected as a result of routine testing – at that time we (the medical profession) did not have the resources or a standard effective method of remediation to offer – and the routine developmental testing of every child was phased out'.[12]

One of the outcomes of these changes has been that children who are delayed in specific aspects of their physical development but who have not received a medical diagnosis simply 'slip through the net' of services which should be in place to identify underlying factors and provide appropriate remedial intervention or educational support. These children are at risk of under-achieving at school, not because they lack intelligence or motivation to learn but because some of the physical skills which are needed to support and demonstrate intelligence in the classroom are under-developed. Furthermore, it is often assumed by teachers that such children are performing well enough and, consequently, they are not identified as under-achieving or having a special educational need, 'hovering at just below age expectation achievement'.[13] If underlying problems connected to the development of physical skills are not recognized, these children are at increased risk not only of under-performing but of experiencing frustration and developing associated 'secondary' behavioural signs.

While there can be many reasons for educational under-achievement, 'Factors such as home background, attendance, quality of teaching, socio-psychological interrelationships, learning difficulties etc. all come into play. Not all of these are within the compass of the teacher to easily control and alter. However, neuromotor immaturity is one significant factor that through a programme of therapeutic movement exercises, developed by INPP, schools can do something about'.[13] For some children barriers to learning can be removed with appropriate educational input, but children with neuromotor immaturity are less likely to reap long term benefits from traditional educational responses to under-achievement which include:

- Additional teaching to support the area of deficit combined with further practice of the same.
- Diagnosis of 'specific need teaching' in ways which maximize their learning.
- Providing strategies or accommodations for specific needs in the classroom.

The identification of underlying physical factors opens up the possibility of effective remedial intervention aimed at the specific mechanisms at fault.

The INPP Screening Tests have been compiled to narrow the gap which exists between the professions of medicine, education and psychology in identifying children who have physical barriers to learning. The INPP Developmental Movement Programme has been designed to help children overcome some of these barriers.

1.9 WHAT IS THE PURPOSE OF DEVELOPMENTAL SCREENING TESTS?

Screening tests are tests which have been developed based on evidence from research which has consistently demonstrated that a cluster of specific symptoms is often linked to specific disorders or dysfunctions.

Screening tests should *not* be used to form a diagnosis, but rather provide professionals with tools to identify individuals who may need more detailed specialist examination or, as indicators for specific types of evaluation or remediation.

Screening tests are *not* meant to replace standard neurological, educational or psychological examinations or assessments carried out by trained professionals, but they *can* help to detect factors which underlie the presenting problems.

The terms 'screening' and 'assessment' are not interchangeable. Screening is a preliminary process for identifying, from all the children, those who may be at risk of future difficulty in school (e.g., inability to meet academic expectations) and those who may have special needs in learning (e.g., extraordinary abilities and talents or handicapping conditions). In both cases, if screening tests yield high scores for indicators of abnormality the child must be referred for assessment to evaluate whether they require treatment for a specific disorder (e.g., visual problem, hearing deficit, motor training, etc.), adaptations of the regular instructional programme, or to discover if they qualify for specialized educational placement.

The INPP screening tests comprise a series of tests compiled from a number of different sources which have been combined to provide a general picture of a *child's neuromotor skills* and *neuromotor readiness* to respond to the demands of formal education. They should not be used as a basis to exclude children from particular activities or year group but are simply intended to provide an indication of a child's neuromotor performance on a range of skills necessary to support cognitive learning in the classroom.

1.10 WHY ASSESS POSTURE AND BALANCE?

Posture is defined as the reflex anti-gravitational adaptation of a living body to the environment in which he or she lives. Posture depends on reflex acts which occur as a result of the integration of several sensory inputs and rapid adaptive motor reactions, chiefly involving the visual, proprioceptive and vestibular systems. 'Posture means unconscious, inattentive, anti-gravitational adaptation to the environment'.[14] When reflex actions are functioning efficiently and at a developmentally appropriate level, they free 'higher' cognitive

systems in the brain from conscious involvement in the maintenance of postural control. Conversely, if reflexes are not functioning in an age-appropriate fashion, then conscious attention must be diverted to the adaptation and maintenance of postural control at the expense of attention to other cognitive tasks. Posture is also essential to support static balance, to provide a frame of reference for coordination and a stable platform for centres involved in the control of eye movements (oculomotor functioning).

1.11 WHY CARRY OUT ASSESSMENTS FOR BALANCE?

Balance is a continuous dynamic process which describes the interplay between various forces, particularly gravity acting with the motor power of the skeletal muscles. A child has achieved equilibrium when it can maintain and control postures, positions and attitudes.[15] Balance is the end product of cooperation between proprioception, vestibular functioning and vision, mediated by the cerebellum. Posture and balance together provide the bases for motor activities on which all physical aspects of learning depend.

'To have a sense of balance one has to know where one is in space at any particular moment. In vertebrates the point of reference for the balance mechanism is the head. The vestibular system (balance mechanism) informs the brain where the head is in relationship to the external environment. The proprioceptive system informs the brain where the head is in relation to the rest of the body, thus informing it where the head is in relation to its supporting base. Any movement of any part of the body is made with reference to the brain's understanding of where it is in relationship to its structural support (base). With these three inputs the brain can instruct a model of the head and body in relationship to itself and the external world'.[16] Abnormal primitive reflexes in the school-aged child provide evidence of lack of integration in the functioning of these three systems, which are fundamental to the sense of position in space. Problems in control of balance can be manifested in a number of ways:

- Postural control
- Coordination
- Control of eye movements (affecting visual perception)
- Perception – for example vertigo, sense of direction
- Vegetative symptoms – for example nausea, dizziness, disorientation.

Control of balance provides not only physical stability for moving in space but also acts as one of the main reference points for cognitive operations in space, including orientation (knowing your place in space, necessary to navigate through space), directional awareness (needed for way finding, understanding the orientation of symbols, e.g. b and d, p and q, 2 and 5, and being able to read an analogue clock or a compass) and mental operations in space, such as being able to understand that addition and subtraction, multiplication and division are the same processes in reverse.

1.12 WHAT IS THE DIFFERENCE BETWEEN STATIC BALANCE AND DYNAMIC BALANCE?

Static balance describes postural fixation, which consists of stabilized body attitudes. Static balance is necessary to be able to remain still in fixed positions; children who have poor

control of static balance find it difficult to sit or stay still. These children tend to be restless at activities that require remaining in a relatively fixed position, needing to be 'in motion' in order to maintain control of the body. This can be seen as fidgeting when sitting to write or when attending or listening passively but they may have relatively good coordination when engaged in activities which involve action, such as on the sports field.

Some research has pointed to a link between the ability to maintain balance while standing on one leg and specific language disorders.[14]

Dynamic balance describes the various translations and re-adaptations of postural role in performing efficient movements. Children with poorly developed control of dynamic balance will tend to shy away from robust physical activities, or activities which involve translation of position in space – carrying out forward rolls, vaulting over an object – and lack confidence in situations which require rapid adaptive reactions.

1.13 WHAT IS THE SIGNIFICANCE OF POSTURAL CONTROL TO LEARNING?

Posture is not only a neuro-*physiological* function which ensures that physical stability and mobility against the pull of gravity, but it is also 'primarily a central neuro-*psychological* system which embraces a wide range of functional levels from spinal reflexes to higher mental processes'.[17] Postural control is linked to at least three perceptual systems – vestibular (balance), proprioceptive and visual – and dysfunction in any one of these systems or how they operate together can affect the processes of perception on which all higher academic skills depend. Posture both supports and reflects the functional relationship between the brain and the body, to the extent that is has been said that there is nothing in the mind that cannot be seen in the posture.[18]

1.14 PRIMITIVE REFLEXES: WHY HAVE THESE THREE REFLEXES BEEN SELECTED FOR EVALUATION?

Detailed examination of reflex status should only be undertaken by a professional qualified in child development who has undergone specific training in the testing of infant reflexes (doctor, physiotherapist, occupational therapist, INPP trained practitioner, for example). However, for purposes of *education* and *screening*, there are three primitive reflexes that have consistently been shown to act as barriers to learning if they persist in the school-aged child:

1. The Asymmetrical Tonic Neck Reflex (ATNR)
2. The Symmetrical Tonic Neck Reflex (STNR)
3. The Tonic Labyrinthine Reflex (TLR).

1.14.1 THE ASYMMETRICAL TONIC NECK REFLEX (ATNR)

The Asymmetrical Tonic Neck Reflex (ATNR) emerges in normal development at about 18 weeks' gestation, at about the same time as the mother starts to become aware of her

baby's movements. Rotation of the head to one side elicits extension of the arm and leg on the side to which the head is turned and retraction of the opposite arm and leg. This reflex increases in strength during the remainder of pregnancy and should be fully developed at birth in a baby born at full term.

In the first months of life the ATNR plays a part in spontaneous movements, developing homolateral (one sided) movements and is one of the earliest mechanisms for training hand-eye coordination. It is normally inhibited between four and six months of age. (Figures 1.1 and 1.2).

Figure 1.1 ATNR neonate

Figure 1.2 ATNR inhibited about six months

Retention of the ATNR beyond six months of age can interfere with the development of subsequent motor abilities such as rolling over, commando-style crawling, control of upright balance when the head is turned to one side, the ability to cross the midline of the body with affect upon bilateral integration, eye movements and hand–eye coordination. Some observations have indicated a link between retention of the ATNR and failure to develop a preferred side of functioning.[19,20] In the school-aged child, a residual ATNR can interfere with activities which involve crossing the midline, especially control of the hand when writing. If it is present in combination with other reflexes linked to the control of the eye movements needed for reading, it can obstruct reading. Prevalence of the ATNR has been found to be greater in some children with reading difficulties.[8]

1.14.2 THE SYMMETRICAL TONIC NECK REFLEX (STNR)

The Symmetrical Tonic Neck Reflex (STNR) is present for a few days at birth, recedes and re-emerges between five and eight months at about the time the infant is learning to push up on to hands and knees in preparation for crawling. It should only remain active for a short period, as retention can interfere with the next developmental stages of crawling on hands and knees,[†] sitting and standing posture and hand–eye coordination.

The STNR is elicited in a four-point kneeling (quadruped) position. If the head is tilted back (extended) there is an increase in extensor muscle tone in the arms, and flexor tone in the hips and knees (Figure 1.3).

[†] Crawling on hands and knees is sometimes referred to as creeping, particularly in American literature on child development.

Figure 1.3 STNR in extension

If the head is tilted forward (flexed) it results in an increase in flexor tone in the arms, causing the arms to bend, and extensor tone in the muscles of the hips and knees to increase (Figure 1.4).

Figure 1.4 STNR in flexion

While the STNR has an important function in helping the infant to defy gravity in the first year of life, firstly in getting on to hands and knees, and secondly in helping to pull to standing at the side of the cot, playpen or an item of furniture, it should not persist in the quadruped position after the child has learned to get on to hands and knees, or in the upright position once the child has learned to stand unaided. If it fails to be suppressed, distribution of muscle tone in the upper and lower halves of the body is affected by the position of the head.

In the school-aged child this can be most readily observed in sitting posture when writing. When the child looks down at the writing surface, the arms want to be bend (and the legs extend), making the child lean further towards the writing surface, so that in some cases the child may end up almost lying on the desk to write (Figure 1.5). In this case, when the head is raised he/she can sit up, but each time he/she looks down the arms bend. If he/she extends her head the opposite reaction occurs – the arms straighten and the legs bend.

Figure 1.5 Sitting posture typical of an STNR in flexion

In addition to making sitting awkward and uncomfortable, retention of the STNR in the school-aged child can also affect specific hand–eye coordination skills, such as those needed to bring the hand to the mouth when eating. Children with a residual STNR are often messy eaters who find it difficult to bring a fork, spoon or cup to the mouth without spilling some of the contents on the way. It can also interfere with the development of specific oculomotor skills, such as speed of accommodation (the ability to adjust focus between different visual distances) needed to copy from the board or track an object approaching at speed (catching a ball for example), and the vertical tracking skills needed to align columns correctly in maths[21] and to judge heights.

1.14.3 THE TONIC LABYRINTHINE REFLEX (TLR)

The Tonic Labyrinthine Reflex (TLR) is present at birth and is a primitive reaction to gravity which recedes as head control, muscle tone and postural control develop. When the newborn is held in the supine position, if the head is lowered below the level of the spine the arms and legs will extend; if the head is raised above the level of the spine the arms and legs will flex. As head righting reflexes develop in the first weeks and months after birth, the TLR diminishes to be replaced by a series of more advanced postural reactions which facilitate correction of head position in response to movement of the body or the environment. These automatic head righting reactions provide the basis not only for control of balance and general coordination but also a stable platform for the control of eye movements.

Retention of the TLR beyond three and a half years of age is associated with problems with balance, muscle tone, control of the eye movements needed for reading, writing, copying and maths, and can also affect spatial skills. This is because spatial awareness and the ability to manoeuvre and carry out cognitive operations in space depend first on having a secure physical reference point in space.

1.15 WHAT EVIDENCE IS THERE LINKING BALANCE, POSTURE AND REFLEXES TO EDUCATIONAL ACHIEVEMENT?

The concept that neurological dysfunction can underlie problems with learning is not new. Neither is the theory that the use of interventions designed to ameliorate neurological dysfunction can improve learning outcomes.

Developmental disabilities were recognized in the nineteenth century chiefly as two forms of delay – cognitive delay in the case of mental retardation and motor delay in the case of cerebral palsy – but less severe symptoms involving discrepancy between intelligence and more specialized areas of language, learning, communication and social interaction, including early infant autism, only emerged in the twentieth century.

In the 1920s the French were among the first to notice a link between 'motor awkwardness' and learning disabilities,[22] which they sometimes described as 'psychomotor syndromes'. In 1940, R. S. Paine described the presence of several isolated motor signs, such as awkwardness, tremor, hyperreflexia or mild impairments in walking, in children with specific learning difficulties. He also pointed to problems in the perception of auditory or visual information, faulty concepts of space, diminished attention span, difficulty in

abstract thinking and delays in academic achievement being characteristic features of children with learning disabilities. Mild epileptic symptoms were also noted as sometimes being present.[23]

In other countries the term minimal brain dysfunction (MBD) started to be used. MBD was formally defined in 1966 by Samuel Clements as a combination of average or above average intelligence with certain mild-to-severe learning or behavioural disabilities characterizing deviant functioning of the central nervous system, which could involve impairments in visual or auditory perception, conceptualization, language and memory, and difficulty controlling attention, impulses and motor function,[24] but with more than 99 possible symptoms listed as diagnostic criteria for MBD by the 1970s the term MBD was already being rejected as being too broad.

Retention of primitive reflexes as one of the signs of cerebral palsy has long been recognized. In cerebral palsy retention of the reflexes occurs as a result of damage to the brain or abnormal development, which may have occurred prenatally, at birth or postnatally (Bobath and Bobath,[25,26] Illingworth,[27] Capute and Accardo,[28] Fiorentino,[29] Levitt,[30] Brunnström[31]). In cerebral palsy 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. For many years it was assumed that retention of primitive reflexes could not exist to any lesser degree in the absence of identified pathology and, therefore, primitive reflexes were not the subject of investigation in children with less severe motor delays or signs of a specific learning difficulty.

Investigations into the presence of abnormal or immature reflexes in individuals with specific learning difficulties emerged from various schools of thought in the 1970s. In 1970, an occupational therapist at the University of Kansas, USA, carried out a study in which she compared the reflex levels of a group of neurologically impaired children with a group of children with no known neurological impairment. Every one of the group diagnosed with neurological impairment had abnormal reflexes. Eight out of nineteen subjects in the 'normal' or comparison group also showed some reflex abnormalities and it was subsequently found that of these eight, one had behaviour problems and the remainder had either reading and/or writing problems.[32]

In the same year, also at the University of Kansas, Barbara Rider, another occupational therapist, set out to assess the prevalence of abnormal reflex responses in normal second grade children, comparing their results to a group of learning disabled children. She found that the learning disabled children had significantly more abnormal reflex responses than the normal children. Using the Wide Range Achievement Test (WRAT) scores as an independent measure, she compared WRAT scores on the basis of whether there were abnormal reflex responses or not. Children with integrated reflexes scored consistently higher on the achievement tests than those with abnormal reflexes.[33]

In 1976 at the University of Purdue, USA, Miriam Bender examined the effect of just one reflex, the Symmetrical Tonic Neck Reflex (STNR) on education, and found that the STNR was present in 75% of a group of learning disabled children but not present in *any* of a comparison group of children who had no history of learning disabilities. She also developed a series of exercises designed to help inhibit the STNR, and observed that many of the children's presenting symptoms improved.[34]

In 1978, Ayres, the creator of Sensory Integration (SI) therapy, observed that one of the major symptoms manifested by children in disorders of postural and bilateral integration was 'poorly developed primitive postural reflexes, immature equilibrium reactions, poor ocular control and deficits in a variety of subtle parameters that are related to the fact that man is a bilateral and symmetrical being'.[35] One of the aims of sensory integration therapy was, 'not to teach specific skills such as matching visual stimuli, learning to remember a sequence of sounds, differentiating one sound from another, drawing lines from one point to another, or even the basic academic material. Rather, the objective is to enhance the brain's ability to learn *how* to do these things'.[35] The objective was modification of the neurological dysfunction interfering with learning rather than attacking the symptoms of the dysfunction.

In 1994, Wilkinson carried out a replica of Rider's 1970 study. She found not only a link between residual primitive reflexes and specific learning difficulties, but also identified a connection between residual primitive reflexes and educational under-achievement. Her findings indicated that one reflex – the Tonic Labyrinthine Reflex (TLR) – underpinned many of the presenting educational difficulties and that there was a relationship between the continued presence of the Moro reflex and specific problems with mathematics.[36]

Goddard Blythe and Hyland in 1997 investigated differences in the early development of 72 children diagnosed with specific learning difficulties compared to children with no evidence of specific learning difficulty using the INPP Screening Questionnaire.[37–39] They found significant differences in the developmental histories between the two groups, with children in the specific learning difficulty group having a much higher incidence of early life events or signs of delay in motor and language development and factors related to the functioning of the immune system. Delays in learning to walk and talk were particularly significant in the group with specific learning difficulties.[40]

Other studies which have investigated the persistence of abnormal reflexes in children with specific reading difficulties have found the Asymmetrical Tonic Neck Reflex (ATNR) to be present in children with reading difficulties,[6,8,41] a cluster of abnormal primitive and postural reflexes present in a sample of children diagnosed with dyslexia[7] and in children with attention deficit disorder.[42]

Investigations into the incidence of abnormal primitive reflexes in a sample of 672 children in seven mainstream schools in Northern Ireland between 2003 and 2004 revealed that 48% of children aged 5–6 years (P2) and 35% of children aged 8–9 years (P5) still had traces of primitive reflexes; 15% (49) of P5 children had a reading age below their chronological age. Of these, 28 also had elevated levels of retained reflexes. Elevated levels of retained reflexes were correlated with poor educational achievement at baseline. In the younger group (P2) it was found that retained reflexes were correlated with poor cognitive development, poor balance, and teacher assessment of poor concentration/coordination. Neurological scores and teacher assessment at baseline predicted poorer reading and literacy scores at the end of the study.[3]

Some research suggests that children growing up in areas of social disadvantage may also be at greater risk of educational under-achievement, not only as the result of lack of appropriate stimulation in terms of opportunity for language development and reading, but also because of immature motor skills.[43] Empirical findings also suggest a link between neuromotor immaturity, as defined by the continued presence of primitive reflexes, and some behavioural problems in children.[44]

1.16 WHAT EVIDENCE IS THERE THAT INTERVENTION IN THE FORM OF MOVEMENT PROGRAMMES AIMED AT THE LEVEL OF PRIMITIVE REFLEXES IMPROVES EDUCATIONAL OUTCOMES?

Remediation of educational difficulties tends to be primarily aimed at treating the symptom, that is, focusing resources on teaching and practise of more reading, more writing, more spelling and more maths as is considered necessary. While this can be beneficial if the problem is a direct result of deficit in teaching or the learning of foundation skills, it will not ameliorate difficulties which arise as a result of defects in underlying physical skills which support higher aspects of learning.

The concept of using motor training programmes to improve learning is not new either. Kephart,[45] Frostig,[46] Getman,[47] Cratty,[48] Barsch,[49] Ayres,[35] Belgau,[50] Kiphard and Schilling[51] and others all advocated and developed perceptual and developmental screening and training programmes to improve the perceptual-motor skills of young children to enhance learning outcomes. In 1979 Blythe and McGlown[37] developed the INPP programme for use with individual children; it was aimed specifically at inhibiting primitive reflexes and stimulating the development of more mature postural reactions. A body of research into the effects of intervention programmes aimed at integrating primitive and postural reactions has gradually accumulated over the last 30 years, beginning with small-scale independent studies which have indicated, first, that primitive reflexes can and do respond to specific physical interventions and, second, that maturation in reflex status is accompanied by improvements in coordination and educational measures.[6,52,53]

In 1996, the INPP clinical programme was adapted for use in schools. Research carried out on this programme has consistently shown:

1. There is a significant decrease in active primitive reflexes and improvement in measures of balance and coordination in children who followed the programme compared to control and comparison groups.
2. There are improvements in drawing and reading in children who had both abnormal reflexes and who were performing below chronological age in these skills before introduction of the programme.[54–57]
3. Empirical evidence provided by reports from teachers and head teachers indicates that there are improvements in behaviour,[58] particularly playground behaviour, children are quicker to settle at lessons following the exercises and there are noticeable differences in children's poise and posture.
4. In one study carried out in Northumberland, UK, five children had been referred to the Behavioural Support Service in the area. At the end of the first term on the programme, all of the children were removed from the support service's list despite the fact that no specific behavioural intervention had been given in the intervening time.[58]
5. A follow up study carried out in Germany two years after a cohort of children had completed the school programme found that the participants had maintained the gains they had made two years after they had completed the programme.[59]

The INPP tests and developmental exercises have been developed based upon evidence which has consistently showed that:

1. There is a relationship between children's neuromotor skills and performance on motor-dependent tasks.

2. Maturity in the functioning of the central nervous system may be inferred from children's neuromotor skills.
3. Residual primitive reflexes respond to the INPP developmental exercise programme.
4. Improvement in neuromotor skills can have a positive influence on learning outcomes.

Factors assessed in the INPP screening tests:

- Balance
- Proprioception
- Primitive reflexes: ATNR, STNR and TLR
- Oculomotor functioning (convergence, fixation, saccades)
- Auditory recognition of visual symbols
- Visual perception
- Visual integration
- Visual-motor integration
- Spatial awareness

1.17 HOW TO USE THE SCREENING TESTS

The following screening tests are intended for use by teachers, doctors and other professionals involved in the development and education of children from five years of age.

The tests are for screening purposes only and should not be used as the basis of a diagnosis, but they may be used to:

1. Identify children with neuromotor immaturity and related difficulties.
2. Identify children likely to benefit from the INPP Developmental Movement Programme for use in Schools.
3. Identify children who have issues related to neuromotor immaturity, visual-perceptual problems or auditory processing deficits who should be referred on for more specialized assessment, diagnosis and intervention.
4. Provide a system of evaluating progress following use of The INPP Developmental Movement Programme for use in Schools and for the evaluation of the other intervention programmes.

While the screening tests may be used as separate items for purposes of identification and evaluation, The INPP Developmental Movement Programme should *only* be used following assessment using the age-appropriate screening tests. The screening tests may be used before and after intervention to evaluate progress.

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