

Why Is Motor Development Important For Academic Learning?

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June 2002

A child's academic ability has traditionally been thought to be an indicator of intelligence and consequently considered to be a function of the cerebral cortex. However, learning is not a process that takes place solely in the higher centres of the brain. Many factors determine how a child responds to educational methods including a number seemingly unrelated to academic ability. A child needs to feel comfortable and secure within the school environment to flourish and take an active role in school life, consequently conditions that affect how a child interacts with peers and teachers can impact on learning ability. Children can be insensitive to the needs of others and if an individual draws attention to itself by being 'different', their basic need to conform and be part of a group will not be satisfied. Clumsiness, messy eating, speech disorders or slightly different physical attributes can alienate a child and affect self-confidence to the extent they may withdraw from the main group. This child may soon learn to compensate for their predicament by using defensive actions to excuse themselves for their behaviour such as pretending to be unfriendly in order to avoid close contact with others. A physiological abnormality can lead to a psychological problem that adds to the discomfort felt by a child. The physical condition of an individual therefore has implications on academic performance beyond the more obvious functions such as the ability to see and hear clearly.

To benefit from an academic education a child has to be able to receive and integrate incoming data via various sensory inputs; process it; and then have the means to express itself. A problem with any one of these stages will hinder the learning process. A child also needs to have mastered a certain degree of self-control by a relatively early age in order to cope with the daily demands of school life. Failure on the child's behalf to control immature urges and reactions will reduce their ability just to sit, listen and learn. American educational philosopher John Dewey wrote

....the crucial educational problem is that of procuring the postponement of immediate action upon desire until observation and judgement have intervened. (Experience and Education)

The 'ability to look before you leap' has benefits throughout life; however, the level of self-control attainable by an individual is not necessarily down to willpower alone. Neural connections formed in the early years of life, determined by genetics, the environment and how the child responds to it, will influence how much control can be asserted. If connections are not established between the body and the higher levels of the brain, a vital link in the 'processing chain' may be lost. Movement forms these connections between the brain and the body and repetition of that movement strengthens and ensures the survival of that connection. The formation of these connections (neural networks) has been studied by neuroscientist, Gerald Edelman who developed the theory of neuronal group selection (TNGS), he states that

...groups of neurons compete in the course of brain development, with surviving groups subject to a second selection in which specific pathways and synapses are strengthened according to whether they yield good or useful outcomes to the organism.

He coined the phrase 'nerves that fire together wire together'. Edelman speculated that a group of neurons in the brainstem are able to sense what is 'good' and 'bad' for our survival. For example, a newborn knows it is better to be full than hungry, warm than cold and possibly in the early years to move has more benefits than being still. This could also explain why children love repetitive games and nursery rhymes as they can learn to predict outcome and sequences that help consolidate their understanding of the world. Edelman says

It is up to the organism to determine which sources of stimulation are significant without either having to be told or arriving at a decision through a logical process.

Stimuli that result in actions deemed to be good by the value system cause neurons to fire simultaneously consolidating the connections currently active. The fact that infants all over the world perform the same stereotyped movements suggests that the brain attaches significant importance to their execution. Giulio Tononi from the Neurosciences Institute in San Diego writes of Edelman's theory.

The old part of the brain has neurons that are connected to all other neurons and fire when something significant to the animal happens. They are dormant when the animal is asleep, and only fire when the animal is awake. They fire in response to stimuli from the environment or from within the person's body, but only if that stimuli has significance, triggering the release of neurotransmitters. Interestingly, they also fire when previously value-free events begin to acquire value, that is, when events, which had formerly not been meaningful, acquire meaning of some sort.

Balance is the first sense to develop and the only sense to be fully myelinated at birth. As all sensation is channelled via the vestibular system to the higher brain, stimulation of the balance system is vital to help lay the foundation for development of all the other senses essential for later skills. Early movement defines the structure and consequently the function of the brain. Movement is key to developing the interface between an infant's brain, the body and the outside world. As early as five weeks after conception the embryo will begin to react to outside stimuli starting with a withdrawal from contact. As the withdrawal response lessens, the primitive reflexes that will allow the newborn to survive in early life begin to emerge. These reflexes are automatic, stereotyped movements mediated from within the brainstem and do not involve the higher centres of the brain. These involuntary movements start the training process that will eventually help the infant to develop conscious, i.e., voluntary control over movement, so paradoxically early involuntary reflex activity helps to promote voluntary control.

After the first year of life the primitive reflexes should no longer be active having performed their function but remain dormant unless required again due to brain injury. If they persist past this stage the development of the postural reflexes may be impeded preventing the child from gaining voluntary control over aspects of movement and behaviour. The movements contained within the reflexes enable the helpless newborn to progress to an infant that can start to interact with their immediate environment. It is therefore imperative that these movements are performed to a sequence in order to proceed through the reflexes to prepare the way for the next developmental stage. The primitive reflexes are also known as survival reflexes. The chances of survival increase once a child is mobile so perhaps they could also be viewed as motor development reflexes because they promote voluntary muscle control by body segment to eventually prepare the infant for crawling and walking.

True voluntary movement occurs in response to stimuli, that is, we react to something we sense. The level of motor ability is therefore linked to sensory development. At birth the senses, apart from balance, are immature due to a lack of stimulation. For example, vision will be poor because there is little visual stimulation inside the womb. The automatic movements of the primitive reflexes provide the stimuli required to train the senses. A stimulus-bound newborn has no choice but to follow the movement of their own hands waving in front of their face thus developing the oculo-motor muscles responsible for eye movement. If the sensory organs are incapable of relaying signals to the central nervous system, or the signals received do not match data coming from other inputs, the subsequent motor act will be based on inaccurate information. Likewise, if motor patterns are deficient or absent the child is denied movement that in 'normal circumstances' would help to fine tune the nervous system ready for the next stage of development. This complicates the problem, at each stage the nervous system will need to compensate for deficiencies in order to adapt to the environment. As biologist Herbert Spencer wrote

Each faculty acquires fitness of its function by performing its function; and if its function is performed for it by a substituted agency, none of the required adjustment of nature takes place, but the nature becomes deformed to fit the artificial arrangements instead of the natural arrangements.

The ability of the human organism to adapt to its environment can compensate for a number of abnormal adjustments due to developmental problems. However, as a child grows the system is

put under increasing amount of stress in more challenging situations such as the classroom. In addition to the fine motor skills required for activities such as using a pencil, a child also has to deal with sitting still and staying quiet for longer periods than has previously been experienced. The logistical, social and academic demands of school life can create an 'overload' in a child that has not been able to develop a satisfactory degree of control over their movement and behaviour. In the classroom, a child's nervous system has to be capable of inhibiting unwanted reactions to the array of stimuli bombarding them at every moment of the day. Inhibition is a vital function performed by the central nervous system. Physiologist Sir Charles Sherrington on reflex activity wrote

...to refrain from an act is no less an act than to commit one, because inhibition is co-equally with excitation a nervous activity. (The Brain and Its Mechanisms)

Inhibition can occur at both subconscious and conscious levels. At a subconscious level, it is facilitated by inhibitory neurotransmitters that prevent a neuron from 'firing' if not required for the current activity. For example, reciprocal innervation (also known as Sherrington's rule) is the process that helps to co-ordinate muscle activity by inhibiting an antagonist muscle from contracting when its opposing muscle is initiating movement. This reduces resistance and the possibility of damage to the muscle whilst limiting friction on the joint itself. Conscious inhibition is the ability to refrain from an action, as Dewey states 'postponement of immediate action upon desire'. Without this ability the child will have difficulty in preventing inappropriate reactions to stimuli that could be deemed disruptive behaviour by the teacher. Being able to inhibit a motor act is a motor act in itself because to not react to a situation is still a reaction.

To sit still for any period of time requires conscious intervention from the child to prevent a response to every distraction in a class. Consciousness is a function of the highest level of the brain, the cerebral cortex, yet it depends on the structure and function of the supporting lower brain. The brainstem channels signals to and from the body, if a primitive reflex residing at a lower level is still active a 'short circuit' can elicit a response before the sensory signals reach the cerebral cortex. These circuits reduce the ability of a child to intervene at a conscious level leaving them vulnerable to uncontrollable reactions. Neuroscientist Benjamin Libet conducted a number of experiments to determine the role of the conscious mind in decision making. He concluded that

... conscious volitional control may operate not to initiate the volitional process but to select and control it, either by permitting or triggering the final motor outcome of the consciously initiated process or by vetoing the progression to actual motor activation. (The Behavioural and Brain Sciences)

To allow this process to happen requires the correct pathways to channel signals from the sensory mechanisms to the relevant centres of the brain to enable the individual to select the most appropriate motor response based on previous experience. A weakness in the underlying organisation of the brain will impede any process that makes use of them thus reducing conscious control and leaving the child susceptible to unsuitable behaviour.

Instrumental in all motor acts, including inhibition, is the cerebellum or the 'little brain'. The cerebellum monitors and modifies signals from the motor cortex controlling fine muscle control, rapid alternating movements and also organising our thoughts into a logical order. It also controls the 'anti-gravity' muscles of the body that regulate posture. Damage to the cerebellum can result in loss of control over movement and abnormal postures. To perform its function of co-ordinating movement requires information from the vestibular system, proprioceptive input from the spinal cord, visual and auditory areas of the cerebral cortex. The connections between these areas and the cerebellum are developed and consolidated in the early years and are vital for controlling speech, eye and hand movement, swallowing, fine motor and sequencing skills. Retained primitive reflexes may also cause problems with the formation of the cerebellum. The first years of life represent a period of rapid growth in the brain. The presence of primitive reflexes impedes development of the postural reflexes that in turn play a significant role in 'wiring' up the cerebellum. In the absence of signals received from fully active postural reflexes the cerebellum will not develop to sufficiently represent the body's true experience of gravity.

The first primitive reflex to emerge is the moro or immature startle pattern. Its function is to get attention in situations where an infant is surprised by a sudden unexpected event such as

movement or sound (fight/flight response) and may help to break the preceding fear paralysis response. The moro may also play a part in developing the breathing mechanism in the womb and helps the newborn to take its first breath. The moro is usually tested at birth to determine the state of the central nervous system by tilting the newborn forward and then allowing them to drop back a short distance. The moro response involves a momentary freeze with the limbs outstretched, followed by a grasping action with arms and legs usually accompanied by a cry for help. This reaction will be evident in the first months on life in response to any sudden change registered by the senses. This could be a loud noise, change of position or an unexpected appearance in the visual field such as a strange face peering over the edge of their cot.

If the moro remains active past four months it can lead to hypersensitivity to stimuli and prevent a mature conscious response in situations that may challenge the child. The unpredictability and potential for embarrassment following a moro response may cause a child to become wary of situations where they are not directly in control. The classroom can be a moro child's worst nightmare if they cannot predict events that may trigger their fight/ flight response. The stimulus bound child will be on constant alert to their surroundings and have difficulty excluding irrelevant stimuli such as objects in their visual field or other sounds in the classroom. This state can be tiring for the child who may then suffer in the classroom due to fatigue.

A moro child may also have difficulty coping with criticism and an unreasonable fear of failure. This can prevent the child from taking the sort of 'risk' that is essential for learning. If a child can appreciate they will make mistakes and further more that they can learn something from them, it may help to develop maturity and quicken the educational process. Because the moro is the first primitive reflex to emerge its continuation may cause a profound effect on the motor development of the child and can be the foundation for neurosis in later life. If the moro is still present it suggests its function to break the withdrawal reflex is not complete and at times of stress the child or adult may freeze and be incapable of action including speech.

The palmar reflex emerges at around eleven weeks in the womb and is activated by a slight pressure on the palm that results in the fingers closing. This becomes stronger and develops into a gripping action and remains after birth so that any object in contact with the palm will be held onto tightly. At around four to six months it transforms to enable the pincer grip with the thumb and index finger and after many repetitions the child will be able to release an object at will. The palmar is also connected to feeding in the early months and can be triggered by sucking and seen as kneading movements of the hand (known as the Babkin response). If the palmar remains active past three months it can effect muscle co-ordination and possibly problems with speech. Children with this reflex can be seen to 'write with the tongues'. Manual dexterity will be poor of the child fails to develop the pincer grip making hold pencils or performing other controlled hand movements such as handling objects. The effect of a retained palmar may therefore deliver a double blow to the child as difficulties with both writing and speech makes expressing itself a problem.

Closely linked to the palmar and part of the 'grasp' reflexes is the rooting reflex. This allows the newborn to feed by searching out the source of food and then to suck and swallow. A light touch to the cheek or lips causes the baby to turn their head, open the mouth and stick out their tongue toward the direction of the touch. It is the strongest reflex at birth requiring immediate use to prevent it from weakening. If retained after four months control of the tongue will be impeded causing it to stay at the front of the mouth as if ready to suck. This can lead to problem when eating, speech difficulties and poor manual dexterity due to the hand-mouth neurological link.

The importance of movement in developing neural networks can be seen with the asymmetrical tonic neck reflex (ATNR). Movement of the head to one side will elicit the reflex extending the arm and leg to the side the head is facing and flexing the limbs on the opposite side. The ATNR stimulates the vestibular (and vice-versa) of the baby whilst still in the womb facilitating movement, including the first 'kick' felt by the mother, thus developing muscle tone. The asymmetric nature of this movement counteracts the total pattern response of the moro reflex allowing for one-sided actions whilst the opposite remains inactive.

The ATNR movement also provides early training for the hand-eye co-ordination. At the same time the eyes are starting to focus on close objects the reflex ensures they have something to look at by turning the head and arm together. If the hand touches something the connection is made and an

awareness of near and far distance starts to develop. In an experiment similar to this movement, Gerald Edelmann found that three-month-old babies would try desperately to make contact with an object held at about arms length. The baby's head, arms and legs wave frantically in an effort to explore the curious looking toy until eventually one hand touches it. Edelmann observed parts of the brainstem 'lighting up' the moment contact was made. When the baby is given the same task the next day it takes less time for contact to be made until finally the task is completed with ease a number of days later. Edelmann believes that the firing of neural circuits measured in the brainstem is the act of the value system consolidating the current neural connections operative when the 'significant' event occurs.

A retained ATNR can make cross-pattern crawling and creeping difficult which is an important stage for further development of hand-eye co-ordination and integration of the left and right hemispheres in controlling movement. A child with a retained ATNR is a child in two halves as movement of the head to either side activates an inappropriate reaction in the limbs. The inability to use both sides together prevents the child from developing a preference for a dominant hand, eye, leg or ear. All actions then have to be made consciously as there is no automatic choice when performing actions involving the limbs. The lack of integration between the left and right hemispheres may also cause difficulties with language as the right side may fail to communicate with the left side to effectively express the child's thoughts. An active ATNR will also prevent the child from developing far-distance vision if the eyes are bound at arms length due to the movement of the arms in response to the head turning. Handwriting can suffer for a child of school age with an active ATNR. As the child turns the head to look at the page the arm will want to extend and the hand open making it difficult to maintain a straight line. The amount of effort required to maintain an acceptable level of handwriting increases the time it takes to complete even a few lines to the extent the child may be assessed well below their true level of ability.

The tonic labyrinthine reflex (TLR), as the name suggests, is activated by changes to the position of the head forwards or backwards in relation to the spine. If moved forward the arms and legs flex and if the head is moved back the limbs extend, both actions help to build muscle tone. By the age of six months this response should have been modified to enable head movement in accordance with the developing head righting reflexes, a postural reflex. The head righting reflexes are vital for maintaining balance and control throughout life and if impeded by a retained TLR will not function efficiently. The importance of the role the head righting reflexes perform in relation to health and function has only recently been recognised by the medical world. In 1989 the International Union of Physiological Sciences Conference debated the head-neck sensory motor systems as a factor in movement and balance. As a result, over one hundred papers were written on the subject in the following three years. In the editor's preface to the publications Berthoz wrote

The need for a thorough analysis of all aspects of head movement control is all the more important because head movements are a core element of orienting behaviour involving a number of interactive sensory and motor systems.

If the TLR remains active thus preventing the development of the righting reflexes the child will experience problems with balance as it will interfere with normal vestibular activity. Maintaining balance whilst performing everyday actions such as walking and running will be difficult as movement of the head alters muscle tone and constantly effect their centre of gravity. Gravity provides the only constant input in a world of many variables. If the child lacks the sense of security and 'reference point' that this provides they will struggle to register their position in relation to immediate surroundings. Because the eyes use the same circuit at the balance system, the vestibulo-ocular reflex arc, problems with the head righting reflexes may therefore impact on vision. Vision and data from the proprioceptive sense (input from the vestibular, muscles and tendons) is vital for balance. A TLR child will have a mismatch between the two and will rely heavily on vision for balance rather than proprioception leading to tiredness from the excessive effort of trying to stay balanced.

If the head righting reflexes are impeded by a retained TLR, poor posture is likely to develop as the child will have to consciously hold their position in the absence of reflex activation of the postural muscles. The constant inappropriate muscular activity create an imbalance as some muscles become weak through lack of use whilst others become tense to substitute for lack of support elsewhere. A child with poor posture may tire more easily than others due to the excessive effort

required just staying still. A child looking down at the desk will struggle to sit upright as their arms and legs will flex and remove their support.

An active TLR may be accompanied by a retained symmetrical tonic neck reflex (STNR), as it will remain in an attempt to inhibit the TLR. The STNR will prevent a child from creeping and crawling. These are important stages in motor development as the activity integrates sensory input from the visual, vestibular and proprioceptive systems as the child learns to move around their world for the first time. The movement helps the child to appreciate distance and their position in space, i.e. when an object is getting bigger in the visual field you will soon bump into it! The alternating movement of the hands in creeping draw the eyes to focus at arms length and cross the mid-line, skills that will be of use when the child learns to read and write.

The symmetrical tonic neck reflex (STNR) as mentioned above inhibits the TLR and helps the child to defy gravity and come up onto all fours. However, whilst the STNR is active the child will not be able to move forward as flexion of the head causes the arms to flex and the legs to extend, extension of the head results in the opposite. The STNR also helps to train focusing the eyes. When the head extends the child sits up and focuses on distant objects, with flexion of the head the child leans forward adjusting the eyes attention to near objects such as the floor. An retained STNR in a child of school age may have a slumped attitude with the legs extended sitting and may have difficulties readjusting vision from the blackboard to their desk.

The presence of a number of primitive reflexes after one year of life will impede the development of reflexes mediated at midbrain level known as postural reflexes. The emergence of these higher brain reflexes is a sign of maturity in the central nervous system allowing for more voluntary control over movement. The postural reflexes can be divided into two groups, the righting reflexes and the equilibrium reactions and help to control stability, balance and recovery from loss of balance. The absence of the postural reflexes leads to clumsiness and poor co-ordination that can interfere with the educational process in a number of ways. As mentioned earlier a clumsy child may become excluded from the main group resulting in insecurity and low self-esteem.

Problems with balance can cause difficulties with sequencing and processing data making it hard to concentrate. If a child cannot make sense of the outside world they will struggle to learn due to the difference between what they perceive to be right and what the teacher says is right. Self-esteem will suffer as the child will start to believe they must be stupid because not only do they get things wrong, they cannot understand why they are wrong! If their efforts are judged to be inadequate they may decide to give up and so become labelled difficult or just not academic material leading to remedial action. However, if the method involves doing more of the same, only at a slower pace, this may re-enforce the child's belief that they are indeed stupid because even with extra tuition they may still be unable to 'get it right'.