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Early Reflex Development, Links between Movement and Vision, and Possible Repercussions for Optometric Care

Bernie Eastwood, Duncraig, Australia

ABSTRACT

In our clinic, we are seeing more children who are less able to control their own bodies in space. They are unable to demonstrate age-appropriate ipsilateral and contralateral movement, upper and lower body control, or postural control. They will often demonstrate retained or poorly integrated primitive reflexes, and needless to say, eye-motor control is also poor.

In education, these difficulties can manifest as an inability to sit still in the classroom, reading without fluency, and poor handwriting. Recently, when I asked a parent "what moving" their child was doing, I was advised of the number of times the family had changed address. This concerning response reflects society's changing concept of what type of movement experience is appropriate for children and raises questions regarding what impact today's culture and environment may have on the foundations of movement development in a young child. Many playgrounds have been stripped of certain styles of play equipment due to safety and litigation fears, backyards are shrinking, many families have both parents in full-time work, and there can be an excessive use of devices that unnecessarily restrict infants' natural movement.

Rapid advances in technology provide benefits and advantages across many diverse areas of life, but these benefits may not extend to the development of good foundations of movement in childhood. Ironically, these advances in technology have also allowed us to gather evidence through in vivo neuroimaging that movement development and cognitive development are more closely related than previously thought.

As optometrists, we are aware that eyes guide motor movement. Researchers across many disciplines agree that infants continue to learn by building on prior sensory-motor experience to plan, to perform, and to perfect their actions within their environment. This literature review reflects on what we currently know about the process of how movement begins in early childhood and what advice we may be able to provide to the families and the children in our care as a result.

Keywords: primitive reflexes, vestibulo-ocular reflex, vision and movement development, vision therapy

Introduction

What Is the Relationship between Vision and Movement?

Vision is the egocentric representation of an individual's world. It is initially created through action and is further developed through interactions and meaningful experiences involving vision, auditory, speech, and thinking. Vision guides action and is created to derive meaning and to serve the needs of the individual. Vision as an adult is the product of years of maturation and integration of all sensory experiences. For successful movement, the brain uses information from the vestibular, visual, and somatosensory systems to keep the eyes stable.[1] Aspects of visual function can be broken into four key areas: Orientation, Organisation, Selective Attention, and Higher Level Visual Functioning.

Orientation is described as a bottom-up process necessary for the balance and posture of the individual. This awareness of working against gravity, or the "which way is up?" process, is driven by the environment and is constant.[2] *Organisation* allows the individual to create an internal map of where they are in the environment, with reference to everything else in the environment within space and time, and allows for efficient mobility and orientation.[2] *Selective Attention* is the intention to acquire information from the environment. It regulates our awareness and impacts how we extract, organise, and use the information from our environment.[3] *Higher Level Visual Functioning* involves the visual perceptual and cognitive skills that through previous experiences bring meaning and understanding to a task once attention has occurred.

Some researchers suggest that basic functions such as sensory and motor processes mature first and are followed by areas involved in top-down control.[4] Other researchers suggest that development may be equally as long in motor and cognitive areas, with both continuing to develop into adolescence. This suggests that their functions, and hence their development, could be highly interconnected.[5]

Some Early Influences on Motor Development

While the body possesses many types of reflexes that differ in many ways, the overriding property of all reflexes is that the same stimulus will always give the same response in a healthy individual.[6]

Vestibulo-Ocular Reflex (VOR)

Reflexes of any kind play a dominant role in early life, and the VOR is responsible for the appearance of some of the earliest eye movements.[7] This reflex, therefore, provides some of the first influences on the motor development, orientation, and localization abilities of an individual.[8] The vestibular system is the only sensory system that is developed and functional at birth.[9] The VOR is poor in the neonate, but it begins to normalize around 2 months of age[9] and so maintains the visual control early in life.[8]

The VOR is responsible for stabilising the retinal image when the head moves by counter-rotating the eyes in an opposite direction to the head but at the same speed.[7] The function of the VOR is to allow for orientation of the visual system that best compensates for any changes in position and orientation of the head. It is driven by the vestibular system rather than the visual system.[7]

The VOR is an old brainstem reflex; however, it has the capacity to change with changing environmental circumstances. Vision is the stimulus for many adaptive changes of VOR performance. The labyrinthine receptors that provide the input for the reflex do not receive direct information about the eye movements.[7] This lack of rapid feedback in the system means that the VOR must be continuously calibrated by short- and long-term adaptations to correct for any error induced by visual or vestibular changes. The errors are sensed by vision, which can then recalibrate the VOR by a process called motor learning or VOR adaptation.[7] In the case of damage to the vestibular system, abnormal vestibular sensations that oppose information coming in from vision and somatosensory systems can re-establish balance through adaptive and repair functions that are carried out by the cerebellum.[7] This raises an interesting question for those we see in clinic with ongoing vestibular problems. Anecdotally, they will often have binocular vision problems of varying kinds. Could it be that the vestibular system is unable to adapt and repair itself due to the inconsistent information coming through from the poorly integrated visual, vestibular, and somatosensory systems? If all three systems are bringing in conflicting information of varying degrees, then on which one does the cerebellum base its repair functions? If, during early development, a child experiences a wide range of movement to improve the accuracy and efficiency of information flowing from vestibular, visual, and somatosensory systems, might it be possible to lessen the impact of insults to the vestibular system later in life?

A study by Charpiot et al.[9] on the VOR and balance maturation demonstrated that balance control is still under development between the ages of 6 and 12 years. This development of balance is thought to be due to the considerable improvement during this time in the use of vestibular and visual inputs. The implication is that while the vestibular and oculomotor systems are very functional by these ages, there is still maturation of the vestibular ocular pathways and the sensory organisation involved in the control of balance.[9] This developmental relationship could be viewed in a different way, whereby continuing to stimulate balance and sensory organisation through movement, continuing the maturation of the oculomotor system. The study did no longitudinal evaluation to compare the movement experiences of the individuals with changes in their VOR and balance.

The Oculomotor System

The oculomotor system was previously thought to be developed and functional at birth and that genetics played the only role in its functional ability. This idea is not supported by the research of Dr. Richard Bruenech. The extraocular muscles consist of two different muscle types that possess different fibre make-up. Cross-striated muscles make up around 80%, while a smaller muscle, the feldenstruktur, makes up on average 20%. Variations of 12 to 30% can be found between individuals.[10]

The feldenstruktur muscle fibres receive nerve innervations in a ratio of 1:1. This allows for an amazing level of precision of movement. These fibres are responsible for the stability of fixation and are slow to fatigue due to their slow contraction.[10] A higher proportion of feldenstruktur is thought to be reflective of a higher reading function, and feldenstruktur are not present from ages 0-5 years.[10] Thus, early proprioception must come from the sensory aspects of vision, the vestibular system, and the somatosensory systems. Out of this integration then come the feldenstruktur and the development of finer oculomotor control.[10] This research would suggest that movement experienced by children less than 5 years of age is extremely important so that strong associations between all the sensory channels can develop for ultimate oculomotor control.[10]

The impact on development of movement when the sensory aspects of vision are not present was demonstrated by Prechtl et al.,[11] who made video recordings of 14 totally blind infants with no evidence of brain damage. Their aim was to observe blind infants and to compare and contrast motor patterns to those of sighted infants.

Early general movement until around 3 months of age was found to be no different in the two groups; however, signs of developmental delay began at the start of the third month with head control. There was a lag in head control noted in blind infants when they were pulled from a supine to a sitting position. In a normally developing infant, under the control of the vestibular system, the head is kept in the horizontal plane, but this was absent in the blind children until at least the end of the first year. The suggestion from the study was that delays in the development of vestibular function occurred due to the inability to calibrate with vision.

A description of fidgeting was given by the researchers to describe the arm and leg actions of the infant when lying down. In the sighted infants, this occurred at around 9-15 weeks of age. In the blind children, these movements were jerky and exaggerated and continued until around 8-10 months. This prolonged and exaggerated period of movement noted in the blind children was thought to be a compensation for the inability of vision to assist in the integrated development of proprioception.[11] Additionally, when a small cube was placed in the hands of the blind children, a head turn towards the cube was initiated. Without the input of vision to assist the blind children in the persistence of the head turn towards the object of interest, they eventually lost the orientation response of the head. Sighted children maintained the head turn.

This study's recommendation was for early intervention to help compensate for the lack of vision;[11] however, there was no suggestion as to what the specifics of the early intervention might be.

Primitive Reflexes and Early Head Control

Primitive reflexes are automatic, involuntary movements that are controlled by a primitive part of the brain, develop during pregnancy, and are still present at birth to assist the newborn baby with their strange new environment. In the early development of the visual system, primitive reflexes such as the tonic labyrinthine reflex (TLR), symmetrical tonic neck reflex (STNR), and asymmetrical tonic neck reflex (ATNR) assist with the beginning foundations of location in space, hand-eye coordination, inward and outward movements of the eyes, eye teaming, depth perception, and focus.[12]

Most primitive reflexes should be integrated (have disappeared) by around 6-12 months of age, to be replaced by what are called postural reflexes that are controlled by more complex and trainable parts of the brain. Postural reflexes emerge in the first 12 months of development but can take up to age 3 to 3.5 years to become fully developed.[6] In the first 3 years of life, postural reflexes are constantly undergoing recalibrations as new motor skills are learned.[6] The development of postural reflexes begins with the control of the head and the continuous interaction between reflexes and postural control.[6] Proprioception within the neck mediates signals passing to and from the vestibular system and the body. A mismatch can create problems with both muscle tone and control of movement.

Postural control and stability should be able to be maintained without interference from changes in head position.[6] It is the timing of the messages, by way of the visual, vestibular, and proprioceptive systems and as modulated by the cerebellum, that provides perceptual stability in the world. When primitive reflexes are found to be lingering in the brainstem, there is interference with cortical processing, and there will be a direct impact on the development of the cerebellum.[12]

Programmes Based on Early Motor Movement Development

Institute for Neuro-Physiological Psychology (INPP) and Rhythmic Movement Technique (RMT)

The premise behind the development of INPP and RMT is the need to integrate primitive reflexes in a sequential manner so that postural reflexes can develop and in so doing form the basis for all later learning and behaviour. Both techniques are in agreement that solid development of motor skills early in life reduces the possibility of cognitive issues later in life.

"Sensory experience and arousal are just the first phases of perception. While the sensory systems provide information about the environment, (feeling) *integration* of sensory experience takes place as a result of action or motor output in response to sensory signals (doing). Mastery of motor skills is supported by posture, and good postural control in the product of an integrated reflex system. In this way, the reflex system is the foundation on which higher postural and motor dependent skills are built. The significance of feedback from the motor system to the sensory systems is illustrated by the development of vision."[6]

Goddard discusses that brain development proceeds in an organised and functional direction, from the lowest-order regions of the brainstem to the highest levels of the central nervous system in the cortex. Within the cortex, there is the organisation of sequentially higher order behaviours that form throughout development, with lower-level functioning being recruited to serve higher-order functioning.

Goddard criticises motor programmes that aim only at trying to improve the functioning postural reflexes. She indicates that if a child has poor balance, postural control, and motor skills and evidence of primitive reflex activity, then programmes such as these will not be beneficial. She differentiates her INPP programmes as they commence at the level of development of the individual, addressing the underlying issues with any primitive reflexes and moving through those in a hierarchical manner.

Goddard also acknowledges the many and varied other influences, such as diet and emotional issues, that impact heavily on her programmes.

RMT was designed by Dr. Harald Blomberg and arose out of his work with psychiatric patients. He suggests that the technique can be used to "treat" conditions from cerebral palsy to schizophrenia.[13] Blomberg describes the series of movements in RMT as being designed to have high levels of vestibular input. He states that it is through the rhythmic movements made by infants that the primitive reflexes are inhibited and that postural reflexes are able to develop.[13] With this emphasis on vestibular stimulation and head control, there is minimal importance placed on the role of vision. Vision is mentioned more as a byproduct of vestibular development rather than as being an essential player in the integration of the vestibular and somatosensory systems.

Movement Development and Cognitive Function

In a number of studies, motor development and cognitive development have been considered as following separate paths. Motor skills were often considered to be fully mature in the individual early in life, with the high-level cognitive functions continuing to develop until much later. Current research is suggesting that motor and cognitive development may be equally as long, with both continuing to develop into adolescence, and that their functions could be highly interconnected and entwined.[5]

The cerebellum may not only be important for motor functions, but also for cognitive functions. The human cerebellum has a precise and regular lattice structure and contains more neurons that the rest of the nervous system combined.[5] Cerebellar activity is greatest when close attention and concentration are required for a new task in both motor and cognition, but the participation of the cerebellum decreases once a task is familiar or practiced. When there is limited cerebellar input, any form of performance is slower, effortful, and varied in its skill.[5] The cerebellum connects to the vestibular system in the brainstem, which links through to the extraocular muscle nuclei associated with ocular muscle co-ordination and movement.[14]

Movement deficits and motor coordination problems are common in children with dyslexia, specific language disorders, autism, and ADHD, but often the emphasis has been on the cognitive issues of these children.[5] In an MRI study of over 200 children, the greatest difference between the ADHD group and the control group was the smaller cerebellum found in those with ADHD. Cerebellar size is also reduced in autistic individuals.[5]

Due to the complex interconnections between the prefrontal cortex and the cerebellum, a dysfunction in one component of the system has the ability to impact the other. The prefrontal cortex and its connection to cortical and subcortical centres, known to be important for movement control, would suggest that the prefrontal cortex has a role with regard to motor function. Another area, the basal ganglia (and more specifically, the caudate) is important for movement control: selecting the movement itself, which muscles to recruit, and with what force the movement should happen.[5] The basal ganglia work with the cerebellum to coordinate voluntary movement.[14]

Movement Development and Other Issues

Many recent articles on movement and children are written with reference to obesity. Many of them touch on the culture and environment of inactive lifestyles as being the greatest contributor, after nutrition, to the obesity epidemic. Movement assists with growth and maintenance of the musculoskeletal system, prevents high blood pressure, and reduces symptoms of depression and possibly stress and anxiety. It improves self-confidence, self-esteem, energy levels, sleep quality, and the ability to concentrate.[15] It has been suggested that there may be key periods where particular importance needs to be placed on physical activity, and these include the first years of life. This period represents an intense phase of motor learning, providing the foundations for later more complex and more skilled performance.[15] Ages 5 through 8 are identified as important for activity so that motor skills can continue to develop and to improve. Early establishment of lifestyle practices in young children is important so as not to reinforce sedentary behaviours, which are more likely to facilitate a sedentary lifestyle in later years.[15]

There are a number of studies linking motor control to mental health issues, from anxiety to schizophrenia. It was interesting to note that many of the articles looked at the issue from the perspective of using motor skills in a predictive way so that early intervention for possible mental health issues could be instigated.

Piek et al.[16] studied how motor performance in infancy and early childhood (4 months-4 years) related to levels of anxious and depressive symptomatology at ages 6-12 years. The study indicated that the variability of a young child's gross motor development was predictive of anxious or depressive symptoms at school age. It could be hypothesized that anyone placed in a situation for which they are ill-equipped will feel anxiety. If this situation were to continue over a period of time, then the likelihood of feeling depressed about the situation could be high. The results of this study and others similar to it could be viewed as more evidence to suggest that motor difficulty in childhood could be a causal factor of some mental health issues. Could directing efforts into the remediation of motor problems earlier in childhood prevent mental health problems for some in later life?

Even artificial intelligence developers are aware of the relationship between sensory information, movement, and development. "The robot is equipped with diverse sensory modalities such as vision, proprioception, and audition, and it interacts with the environment through a sophisticated motor apparatus."[17] Researchers indicate that one of the difficulties with current robotics is not the development of each individual module of a robot, but rather the final integration of the sensing mechanisms with the motion mechanisms to allow for a mature performance. It further goes on to discuss with regard to robotics that the ultimate aim is to create a system that can adapt (learn) by itself using sensorimotor coordination during interaction with the environment.[17]

Conclusion

The question of childhood motor development and how to optimize it for the individual is multifaceted. Many external variables and influences have the ability to impact the progression of motor development. There is also the complex nature of variability between individuals and their incremental development across the differing skills. Throughout the literature, from a diverse range of scholars with differing areas of expertise, there was complete agreement that from infancy, children need to be exposed to a wide range of experiences in the real world involving sensory stimulation and movement. No literature proposed that limiting children's movement was advantageous to development in any way. The debate in the research revolves more around the specifics of the sequence of development, including when maturation is considered complete, when critical periods occur to optimize development, and what is specifically needed to optimize functional brain development. The evidence on the importance of moving in the early years of childhood raises a number of questions and issues for us as optometrists.

- Is the exclusive use of screen-based vision therapy, which provides minimal stimulation to the vestibular and somatosensory systems, the best practice for proper visual development?
- Could the recommendation for vestibular and somatosensory stimulating activities to assist the development of not just visual motor skills but also the cognitive skills in vision processing be advisible?
- It may be of value to see children at younger ages to assess not just vision but screen for movement development. In this way, parents and caregivers can be advised of ways to stimulate both the sensory and motor systems for the best developmental outcomes for vision.
- What is the best timing for our examinations, reviews, and referrals to other movement professionls so that any nesessary interventions are early and place a child in the best position for healthy mind, body, and vision development later in life?
- Advice given to families on the appropriate balance of time spent indoors on devices and time spent outdoors for young and school-age children may be important. Balancing out the use of technology with continued movement stimulation for not just children but adolescents, as it appears that developmental periods extend over greater years than was previously thought.

Parents and educators are at the front lines of child development, and very young children are completely dependent on the adults around them to facilitate this development. If caregivers are not made aware of the issues surrounding childhood motor development, then it requires a consolidated approach from us as professionals to educate, to influence, and to change current behaviours. There is already evidence to suggest a correlation between poor motor skill development and the risk of poor cognitive skill development, increased risk of mental health problems, and poor oculomotor control. Early identification of at-risk children would be highly beneficial. Motor intervention programmes with an appropriate professional for the individual's needs may then be commenced.

This literature review also has heavy implications for education. Traditionally, education does not take the science of child development and overlay it onto the experiences and skills that are necessary before the tasks of attention, reading, and writing may be achievable. Working to advance cognitive skills alone excludes large areas of motor development, which may be equally important. Developmental screening to assess readiness for the classroom would ensure that young children in particular are not expected to perform developmentally inappropriate tasks.

As optometrists, we can change our own behaviours and educate others regarding the importance of continued movement throughout childhood and adolescence.

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Correspondence regarding this article should be emailed to Bernie Eastwood, at bernie@thefocalpointoptometrist.com.au.

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