Level 1

Motor Development

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CONTENTS

Motor development *refers to changes in children's ability to control their body's movements, from infants' first spontaneous waving and kicking movements to the adaptive control of reaching, locomotion, and complex sport skills.*

CLASSICAL AND CONTEMPORARY THEORIES IN MOTOR DEVELOPMENT

Early Pioneers

0584.001 Researchers in the 1930s and 1940s provided the first detailed descriptions of change in infants' motor skills. Arnold Gesell, for example, identified 22 stages in the development of crawling, beginning when infants lifted their heads from a prone position and ending when they could crawl smoothly on their hands and feet. Myrtle McGraw described seven primary stages in the development of walking, progressing from newborns' reflexive stepping movements to independent walking at the end of infants' first year. These early pioneers believed that motor development resulted from neuromuscular maturation – largely autonomous changes in infants' brains, muscles, and growing bodies. From this perspective, rich catalogues of motor milestones would yield insights into the maturation process. Normative descriptions of motor milestones were widely published in books, journals, and newspaper columns and are still the accepted guidelines for informing clinicians, doctors, and parents about the path of normal motor development. However, the early pioneers may have done their job too well. Once neuromuscular maturation became the broadly accepted explanation for motor development and the major skills were amply catalogued, the need for further research dwindled. From the 1950s to the 1980s, motor development was virtually ignored by developmental psychologists.

Contemporary Approaches

In the 1980s, interest in motor development was 0584.002
rekindled as new research methods and sophisticated recording technologies provided improved ways of measuring and analysing infants' motor skills. More important, recent conceptual advances opened a new perspective for understanding developmental change. Neuromuscular maturation has lost its privileged status as the central impetus for motor development. Emphasis on the contributions of peripheral factors, perceptual information, and learning for adaptive control of movements have reinvigorated the field of motor development.

A prominent influence on contemporary re- 0584.003
search is the dynamic systems approach inspired by the Russian physiologist Nicholai Bernstein, and popularized and expanded by developmental psychologist Esther Thelen. On the dynamic systems account, new motor skills may emerge from the confluence of many interacting factors, each with its own developmental trajectory. Each factor must be in place, sufficiently ripe and ready to go, but no factor enjoys privileged status compared with any other. Independent walking, for example, may emerge when infants have sufficient muscle strength, slimmed down body proportions, motivation to go some place, balance control, the appropriate environmental properties to support the action, as well as brain maturation.

A second prominent influence is the perception– 0584.004
action approach inspired by James and Eleanor Gibson. They argue that perception and movement are linked together. To be planned and executed adaptively, actions require perceptual information about the relevant properties of the environment and the body, and the relationship between them. On the other hand, perceptual information typically requires movement to create the relevant structures in light, sound, and other ambient arrays of

energy. For example, exploratory movements of the eyes, head, body, and extremities generate perceptual information in light, sound, muscles, and skin. Actions likewise generate more information for perceptual systems. Perceptual-motor learning is critical for discovering and honing exploratory movements and for discriminating and using the relevant information obtained from exploration.

Importance of Posture

0584.005 On both classical and contemporary accounts, posture plays a central role in motor development. On the classical neuromuscular maturation account, infants' slow triumph over gravity as they acquire increasingly erect postures is evidence of greater cortical control of actions. On the contemporary dynamic systems and perception–action accounts, posture is the biomechanical foundation for action. Manual skills, locomotor skills, and even lifting or turning the head require a stable postural base. Each postural milestone in development (sitting, crawling, walking, etc.) requires learning about a new perception–action system. The first step of learning to control a new postural system is to co-contract large muscle groups. This co-contraction frees up resources and allows attention to be focused on the goal-directed part of the movement. However, co-contraction results in jerky, energetically inefficient movements. After extended practice, muscles are activated in sequence and muscle forces are used sparingly so as to exploit gravitational and inertial forces which impel movements for 'free'.

MANUAL SKILLS: EXPLORING OBJECTS

Reaching and Grasping

0584.006 Arm movements begin before birth. Fetuses wave their arms, produce isolated finger movements, and display coordinated arm–hand movements such as bringing their thumb to their mouth. After birth, infants must cope with gravity outside the buoyant, fluid-filled womb. Newborns' arm-flaps and jerky arm extensions become successful reaching to objects at four to five months. Careful motion analysis shows that infants initially solve the problem of getting their hand to a target in their own way. More sluggish infants must overcome gravity to move their arms from their sides, and more active infants must dampen inertial forces to control ongoing, spontaneous arm-flaps. Like reaching, infants' first grasps are inefficient. They open their hand to the proper shape only after contacting the object. By about eight months, babies can use visual information about object size, shape, and orientation to adjust the shape of their hand before contacting the object. Infants need not look at their hand to guide its shaky path to the target because successful reaching and grasping in the dark occurs at the same time as in the light. However, visual information about the object's location and other properties is extremely important for planning arm and hand movements adaptively. A dramatic illustration is that young infants can intercept moving targets. They do so by moving the hand on the opposite side of their body to the appropriate location before the object arrives.

Apparently, coordination between manual skills 0584.007 and perceptual exploration is fundamental. In addition to hand–mouth behaviours, newborns turn their heads to keep an outstretched arm in view. Older infants use their reaching and grasping skills to bring objects (and fingers) to their mouths, and coordinate visual, tactile, and oral exploration by alternating between looking at the object, turning and fingering it, and sucking on it.

Even a simple reaching task requires balance 0584.008 control. When an arm is extended over the base of support, the centre of gravity is displaced. Before babies' back and abdominal muscles are strong enough to support them in a sitting position, they must use their hands to maintain balance in a 'tripod' configuration. After onset of independent sitting at five to six months, their hands are free to reach, grasp, and manipulate small objects. Over the next several months, infants become skilled at coordinating reaching and leaning so as to prevent falling over.

Using Hand-held Implements as Tools

Once infants master the motor components of 0584.009 reaching and grasping, they can use these skills to extend their own abilities and to bring about rewarding outcomes. Babies bang rigid objects against rigid surfaces to make a noise, but cease banging squishy objects on squishy surfaces. When given a choice between different objects and surfaces, they test various combinations to find the object/surface combination that makes the most noise. Although nine-month-olds can hold a spoon and use it to bang on their high-chair tray, it isn't until several months later that they can manage fine motor control and incorporate the spoon into a complex plan for transporting food to their mouth. Swiss psychologist Jean Piaget was first to describe how older infants separate reaching and grasping into means for achieving ends. For example, after eight months or so infants reach and pull a cloth to bring a toy on the cloth into closer proximity. Similarly, older infants extend their reaching space by leaning forward with a stick in their hand to contact an object. Toddlers use canes as tools to rake in objects out of reach. They show understanding of the relationship between tool and target by turning the cane to the appropriate orientation.

BALANCE AND LOCOMOTION: EXPLORING THE LAYOUT

Interlimb Coordination in Crawling and Walking

0584.010 Precursors of locomotion begin long before infants take their first steps. Fetal and newborn spontaneous arm and leg movements contribute to building and strengthening muscles necessary for later locomotion. Coordination between limbs may already be in place in newborns. When the constraints of muscle strength and balance control are removed, newborn infants produce the ‘crawling’, ‘swimming’, and ‘stepping’ reflexes. They display crawling movements when placed on a gentle downhill slope, swimming movements when put into a pool of water, and stepping movements when held upright on a table. Each of these movements resembles the coordination patterns of later appearing skills. And each shows a U-shaped developmental trajectory: the reflexive patterns displayed by newborns disappear and then reappear months later in altered form. The classical explanation for this trajectory was neuromuscular maturation: as cortex becomes more refined and myelinated, the reflexive movements are inhibited and then reappear under cortical control. Recent research supports the contemporary dynamic systems account – that the central nervous system is not a privileged factor and that peripheral factors may play the pivotal role in development. When stepping infants’ legs are weighted to simulate fat gain, they stop stepping. When non-stepping infants’ legs are held in a tank of water, they step. When non-steppers are held in an upright position over a motorized treadmill, they step. Apparently, the peripheral factors of leg muscles and leg fat were the key factors in the U-shaped trajectory. Infants stop stepping when their legs are too fat and weak. Similarly, the treadmill compensates for leg strength by stretching the leg backward and allowing it to pop forward like a spring.

Crawling is usually infants’ first success at independent locomotion. Many infants invent idiosyncratic styles of crawling at first, such as scraping along on their bellies. However, maintaining balance on hands and knees is highly constrained biomechanically and nearly all infants crawl the same way from their first week on hands and knees – a modified diagonal trot. Practice using idiosyncratic belly crawls is not wasted, however, because ex-belly crawlers are twice as fast and efficient as infants who skipped this phase, once both groups of babies begin crawling on hands and knees. 0584.011

Independent walking typically appears after several upright transitional stages (pulling to a stand, balancing, and cruising sideways using furniture for support). There is a dramatic change in walking gait from infants’ first steps to the toddler years and beyond. New walking is characterized by small steps with a wide space between the feet. Toes point outward and the legs are almost straight. Elbows are bent upward and the palms face the ceiling. Rather than a heel-to-toe progression like adults, infants walk on their toes or plant their whole foot down at one time. This strange gait pattern progressively improves so that by seven years of age children walk like adults. 0584.012

Balance Control

Locomotion requires continual adjustment to disequilibrium by using compensatory sway to keep the centre of mass over the base of support. Sometimes compensatory movements are obvious, as when trying to recover from a fall. Other times, as when just standing or walking on flat ground, it is not as apparent. However, detailed recording shows that the body is constantly swaying, even if movements are invisible to the naked eye. Keeping balance is especially difficult for infants because their body proportions are top-heavy and they fall faster given their short stature. Children rely on several sources of information for balance control: somatosensory information from their muscles, joints, and skin, vestibular information from accelerations of the head, and visual flow information created by the body’s movement. When visual flow is simulated by surreptitiously moving the surrounds (as in a flight simulator), standing adults generate compensatory sways in accordance with the simulated visual flow. Walking infants also respond with compensatory movements, but they 0584.013

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overcompensate and often stagger and fall. Even babies who cannot locomote independently show signs of sensitivity to visual information relevant for balance control by moving their heads in accordance with simulated flow.

Navigation over Variable Terrain

0584.014 Adaptive locomotion requires learning. When newly locomotor infants are challenged with variable terrain, they show little ability to distinguish safe from risky ground. For example, at the edge of a cliff or steep slope, they plunge over heedlessly. (Infants are always protected in such experiments by covering the drop-off in safety glass or having a trained experimenter nearby to provide rescue.) After several weeks of locomotor experience, they avoid risky ground. Surprisingly, learning appears to be specific to each postural milestone in development. For example, experienced crawlers avoid risky slopes, but the same infants attempt the same risky ground a few weeks later after they begin walking.

CONCLUSION

0584.015 Motor development does not stop after infancy. After mastering basic postural, manipulative, and locomotor skills, children acquire a host of more complex activities – writing, playing the piano, jumping, skipping, etc. As in infant development, later skill learning begins with stiff, wasteful, and uncoordinated movements and becomes progressively more rhythmical, smooth, and efficient.

0584.016 Motor development is not an isolated domain. The newest research in motor development focuses on interactions between acquisition of new motor skills and developments in perceptual, cognitive, social, and affective domains.

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Glossary

Adaptive motor control Using perceptual information to gear movements to body properties, environmental properties, and task constraints. Safety, efficiency, and flexibility are key aspects of adaptive modification of movements.

Biomechanics The physical and mechanical principles which underlie movements in living organisms.

Compensatory sway The body's response to a disruption of balance caused by naturally occurring swaying motions. A compensatory sway is in the opposite direction of the disrupting swaying motion so as to bring the body back into equilibrium.

Crawling Forward locomotion with the body in a prone position. Typically, infants crawl on hands and knees, but many infants also crawl with their bellies on the floor, or on their hands and feet.

Dynamic systems approach A theoretical framework espoused by Nicolai Bernstein and expanded by Esther Thelen that views motor development as the result of multiple interacting subsystems, all developing at their own rates and supported by underlying subsystems of their own. New skills emerge from a spontaneous process of self- organization.

Neuromuscular maturation A theoretical framework popularized by Arnold Gesell and Myrtle McGraw that views motor development as the result of endogenous, genetically determined changes in the central nervous system, naturally unfolding body growth, and reorganizations in the coordination of muscle groups.

Perception–action approach A theoretical framework proposed by James and Eleanor Gibson that views motor development and skill learning as inseparably integrated with perceptual development and perceptual learning. The emphasis is on the adaptive control of movements.

Perceptual exploration The process of producing and gathering information about the body and the environment. Can be intentional or serendipitous. Typically involves multiple sensory and motor systems such as looking, touching, mouthing, listening, feeling limb movements, and stimulation of the vestibular apparatus in the inner ear.

Posture The process of keeping the body in balance during relatively stationary positions such as sitting and standing, and during relatively active positions such as crawling and walking. Includes stabilizing the torso to allow for movements of head, arms, and legs.

Stepping reflex The slow, march-like alternating leg movements produced by two- to eight-week-old infants when they are held upright with their feet on the table.

Keywords: (Check)

locomotion; manual skill; motor control; learning; balance control

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Section 1.2 (but NB. this numbering will not be used in the final volume): Bernstein - is forename Ni<u>ch</u>olai, as here, or Ni<u>c</u>olai, as in the Glossary?

Section 3.1: perhaps explain “myelinated”, for the benefit of our elementary Level 1 readership, who may not be familiar with this term?

Glossary, “Dynamic systems approach”: the text is incomplete, finishing “New skills emerge from a spontaneous process of self-organization, where the”; should there be more text, or should we finish at “self-organization”?