The SAGE Encyclopedia of Lifespan Human Development

Motor Development

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The study of motor development is really the study of behavioral development, because motor skills include every kind of observable behavior, from walking and reaching to playing soccer or using chopsticks. Thus, *motor development* has a broad scope. It refers to improvements and decrements in motor skill over the life span and the processes that underlie those changes. This entry outlines several core principles of motor development and illustrates those principles for three basic action systems—posture, locomotion, and manual actions.

Five Principles of Motor Development

Equifinality and Multifinality

Motor development is traditionally portrayed as a series of stages, but this simple characterization fails to capture the equifinality (multiple pathways to the same endpoint) and multifinality (multiple outcomes from the same starting point) inherent in the developmental process. Infants often arrive at the same outcome through different developmental routes; the mature manifestation of a skill in young adults often takes different forms; and elderly adults commonly compensate for decrements in skill in different ways. Individual differences and intraindividual variability are typical, and cultural differences can be surprisingly dramatic.

Body–Environment Reciprocity

Motor actions depend on the physical constraints of both body and environment. Thus, the development of motor actions reflects changes in the fit between body characteristics and variations in environmental properties. To walk upstairs, for example, the walker's leg length, muscle strength, balance control, coordination, and endurance must be sufficient relative to the riser height, tread depth, and number of stairs in the staircase. Changes in either side of this reciprocal body–environment relation alter possibilities for action.

Perception–Action Coupling

Motor development involves changes in psychological functions as well as changes in biomechanics. Because body and environmental constraints are continually varying, perception (and sometimes cognition) is required to guide motor actions adaptively. Optimally, movements are controlled prospectively rather than reactively, and such planning and forethought require perceptual information about possibilities for action (e.g., whether a narrow doorway is passable) and upcoming events (e.g., a car swerving into your lane). Exploratory activity and feedback from movements performed moments earlier generate the requisite perceptual information.

Experience

Generally, basic motor skills such as posture, locomotion, and manual actions emerge in infancy, improve over childhood, become more refined during adolescence and young adulthood, and decline with aging. However, motor development is only age related, not age determined, because experience affects the ages when skills first appear (walking onset at 9 or 18 months), the form of each skill (sitting with legs out or in a deep squat), and which skills are acquired (some infants never crawl, and many people never learn to swim, ride a bicycle, or drive a car). Active, self-generated experience is far more powerful (e.g., children kicking their legs) than experiences that are passively received (caregiver pumping children's legs).

Child-rearing practices and cultural expectations and customs play a large role in determining the amount and variety of experience with particular skills.

Developmental Cascades

Developmental changes in one motor skill can bring about changes in other motor skills and lead to changes in domains seemingly far afield. For example, the ability to sit facilitates multimodal object exploration (e.g., coordinated looking and touching). The advent of crawling instigates improvements in spatial cognition and memory. And the ability to walk stimulates changes in emotional independence and social interactions with caregivers.

Posture

Generally, infants' triumph over gravity proceeds downward from head to feet, starting with keeping the head balanced between the shoulders, progressing through trunk control in a sitting posture, and finally maintaining balance while standing and walking. Manual support of balance allows presitting infants to *tripod sit* with arms propped between outstretched legs and allows prestanding infants to stand or *cruise* sideways while holding furniture for support. Similarly, railings allow competent walkers to keep balance in tricky environments (stairs, slippery ground), and manual supports such as canes and walkers aid balance in older adults.

Equifinality and multifinality are present throughout postural development. For example, some infants acquire a sitting posture with their legs outstretched in a V, some curl their legs in a ring position, and some bend their legs backward in a W. Some adults sit on the floor *tailor style* with their legs crossed and folded toward the body, some sit *prayer style* with the legs folded beneath the body, and some sit in a deep squat.

Body–environment constraints affect demands on balance control. Walking unloaded is easier than keeping balance while wearing a backpack or carrying a suitcase because these functional changes in body proportions shift the center of mass backward or sideways, pulling the body off-balance. Consider sitting submerged in water or on dry land, standing on flat ground or on a slope, and walking on carpet or ice, in each case, the latter environmental property puts more demands on balance. Moreover, every movement of the extremities destabilizes balance because lifting an arm or tilting the head changes the location of the center of mass. Even infants are aware of the central role of posture in providing a stable base for action. They stabilize their trunks before lifting their arms to reach for a toy or twisting their torso to look at something behind them.

Perception is central to postural control because even in apparently *stationary* postures such as sitting and standing, the body sways within the base of support. A torque-induced sway in one direction must be met by a muscle-induced compensatory sway in the opposite direction. Infants are sensitive to visual and proprioceptive information for postural sway, but their compensatory sways are excessive and they often lose balance and fall. By middle childhood, visual control of postural sway reaches adult efficiency and merely a light touch of the hand on a support surface can control swaying movements. Pregnancy induces increased sway in a standing posture, causing pregnant women to rely more heavily on visual information to maintain balance. Older adults sway more than younger adults and have greater difficulty keeping balance when visual information is restricted or when muscle joint information in the ankles is limited.

Experience affects postural development. For example, caregivers in some cultures train infants to sit with special exercises and devices to promote balance, and caregivers in other cultures constrain infants' movements in special swaddles, slings, or cradles. Training accelerates the onset of independent sitting by weeks to months, and constraining infants' movements significantly delays the onset of sitting.

At every point in development, posture provides the foundation upon which other actions are built. Head control sets the stage for effective visual exploration, trunk control provides a stable base for manual actions, and upright posture allows for mature forms of locomotion. Thus, increases or decreases in postural control create developmental cascades into seemingly remote domains of function. Acquisition of a stable sitting posture paves the groundwork for 3-D form perception because sitting facilitates multimodal object exploration, which, in turn, facilitates the acquisition of knowledge about the 3-D of objects. In young adults, increase in muscle tightness leads to limitations in sitting positions that are easy for young children (e.g., tight hamstrings preclude sitting on the ground with legs outstretched), creating increased reliance on furniture. In elderly adults, loss of balance control makes it more difficult to transition between postures, such as moving from sit to stand, thereby curtailing activities and increasing the likelihood of falling.

Locomotion

From infant to young adult, the development of locomotion proceeds from behaviors that require less balance and coordination to behaviors that require more. Within basic forms of locomotion (e.g., crawling, walking, and running), movements become faster, larger, and more efficient. Across all types of locomotion (from walking and bicycling to swimming and skiing), movements become increasingly functional and adaptive. With aging and the accompanying decrease in balance, strength, and coordination, locomotor movements become more constrained and less functional.

Locomotor development presents a veritable smorgasbord of equifinality. The skills on traditional *milestone* charts and in physical education curricula do not begin to capture the variety of locomotor forms displayed in children's everyday activity. Infants' first success at mobility reflects positions that minimize balance requirements—pivoting, log rolling, and various forms of crawling and hitching. Because balance constraints are more demanding while upright, learning to walk is an exercise in creative problem-solving. Infants use falling, twisting, and stepping strategies to initiate a burst of walking and to recapture balance when they want to stop walking. Across the life span, people discover new ways of moving. Infants slither under furniture and back down stairs; children and young adults climb ladders and rock faces; they break dance and ballroom dance, skip, gallop, and hop, and do the butterfly stroke and the Fosbury flop—the possibilities are endless. Elderly adults avoid falling by shuffling, shortening step length, and minimizing time with one foot in the air.

Changes in the body affect locomotion. The gradual slimming of the body from infancy to childhood makes walking easier because the body is less top-heavy. Obese children and adults must compensate for additional body mass by shortening and widening their steps. Loss of strength in skeletal muscles due to aging leads to decreased performance. Similarly, changes in the environment affect locomotion. Walkers must select and modify movements prospectively to cope with variations in the ground surface and obstacles strewn in the path. For some obstacles—steep slopes, high drop-offs, narrow passageways, and so on—walking is impossible and walkers must find an alternative strategy or avoid going. A surprising finding is that learning to gauge body–environment relations does not transfer from earlier to later developing forms of locomotion. For example, the same experienced crawling infants who correctly perceive that a large cliff or slope is impossible to descend will march right over the brink when tested in a novice walking posture. Clearly, infants are not learning fixed facts about the environment or their abilities because possibilities for action change from week to week as bodies grow and skills improve. Instead, infants are learning to generate and use perceptual information about body–environment relations.

Experience affects the timing, form, and trajectory of locomotor development. Experimental studies with infants show that experience standing, stepping, and moving upright facilitates gains in strength and balance and accelerates the onset of walking. A few minutes of daily practice with upright stepping causes infants to begin walking weeks earlier than infants who receive only passive exercise. Similarly, in cultures where parents deliberately exercise upright skills as part of the daily routine, infants walk at younger ages than those from the same ethnic backgrounds who do not receive training. Experience influences the end point of development—multifinality—as well. In cultures where carrying head loads is part of everyday activity, children and adults learn to alter the energetics of walking to carry prodigious loads without increased metabolic cost. In cultures that make running a central part of everyday life, children and adults run marathon distances for sport, travel, and persistence hunting (they run animals to exhaustion). Across cultures, infants' first wobbly uneven steps quickly progress to racing across the floor. The steep development trajectory for walking resembles the negatively accelerated performance curves characteristic of most motor learning tasks. Initial rapid improvements in the first 3–6 months of walking reflect infants' discovery of the relevant parameters that control upright balance and propulsion. The protracted tapering-off period until 5–7 years of age reflects subtle fine-tuning of the parameters. Practice, not merely maturation, underlies improvements, and infants accumulate immense amounts of practice. In 1 hour of free play, the average toddler takes 2,400 steps, travels the length of 9 U.S. football fields, and falls 17 times.

The transition from crawling to walking instigates a cascade of far-flung developments. Compared with experienced crawling infants, novice walking infants move faster, take more steps per hour, travel longer distances, and visit more places. Compared with crawling, where infants' view is largely limited to the ground in front of their hands, the upright posture provides an expanded view of the environment and makes it easier for infants to locate distant objects. Moving upright also facilitates carrying objects from place to place. Carrying objects, in turn, alters infants' interactions with caregivers. Instead of holding up objects from a stationary position to bid for caregivers' attention, walking infants pick up the object, carry it to the caregiver, and consequently receive more language from caregivers about actions on objects.

Manual Actions

Manual actions include prehension of objects by reaching and grasping, exploration of objects by fingering and rotating, manipulation of objects and surfaces by palpating and rubbing, and propelling objects by throwing and rolling. Tool use is a special case of manual actions, in which the tool extends the user's manual skills. Manual actions also include object- and surface-free movements such as pointing, gesturing, and signing. Generally, arm movements appear earlier in development than hand and finger movements; fine motor control of the digits is compromised earlier during aging than gross motor control involving the arms.

Equifinality is endemic in the development of manual actions. More sluggish infants' first reaches emerge through powering up their stationary arms; more active infants learn to reach by controlling the inertial forces of their flapping arms. Infants and young children use a variety of grips to grasp a handled tool such as a spoon or hammer; some grips are more adaptive, such as a radial grip with the thumb near the action end of the tool, and some are less adaptive, such as an ulnar grip with the pinky finger near the action end.

Body–environment relations determine possibilities for manual actions. For example, changes in hand size, strength, and manual dexterity relative to object size, shape, and weight affect whether an object can be grasped in one hand or requires two hands. Similarly, developmental changes in manual skills determine whether a lid can be opened: Two- to 5-year-olds frequently fail even when they know to twist or pull the lid because their hands are too small or too weak to implement the action; similarly, older adults fail because of decreased grip strength and manual dexterity (this is why *child-resistant* packaging inadvertently thwarts elderly or infirm people).

Perceptual information about the location of an object relative to the hand is critical to guide reaching, catching, and grasping. Infants' first reaches are jerky and crooked; the arm changes speed and direction several times prior to contact. The problem is due more to inadequate control of forces than to misjudgments of the relative locations of target and hand. Reaching trajectories improve over infancy, but it takes years before children's reaches are as smooth and straight as those of adults. Infants can also catch moving objects by timing their arm movements so that their hand arrives at the object's eventual location rather than trailing after the moving target, but catching continues to improve throughout childhood. Prospective control of grasping based on visual information for object size, orientation, and substance appears months after infants begin reaching. Planning a grasp for using a tool lags behind simple object grasping because the plan must encompass the eventual implementation of the tool—an action not directly available in the visual scene.

Infants' experience with manual actions begins prenatally as fetuses touch the uterine wall, grasp the umbilical cord, and bring hand to face to suck their thumb. Neonates and young infants show precursors of visually guided reaching, extending, and flapping their arms more frequently while looking at a toy than without a toy in view. Similarly, tool use has its roots in early manual experiences. Fetal hand-to-mouth behaviors become self-feeding with a spoon. Young infants' spontaneous banging and rubbing become preschoolers' hammering and drawing. Exploring relations between objects and surfaces sets the stage for using objects as effective tools.

Experience with manual actions instigates a cascade of developments. A few weeks of training with objects at 2–3 months of age (e.g., putting objects into prereaching infants' hands) accelerates the onset of independent reaching and facilitates object exploration and means–ends behaviors over the next several months compared with infants who do not receive early object training. Moreover, early experiences with objects leads to even more remote accomplishments such as increased sensitivity to causal relations, others' goals, and action efficiency while viewing reaching events. Acquisition of sophisticated manual actions such as typing allows older children to use computer keyboards to complete their school lessons and to use smartphones to communicate with their peers and caregivers on social media.

See alsoAction; Developmental Cascades; Developmental Timetables; Developmental Trajectories; Dynamic Systems Theory; Exercise; Physical Activity; Reflexes

- locomotion
- infants
- crawling
- legs
- walking
- motor skills
- trunk

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Further Readings

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