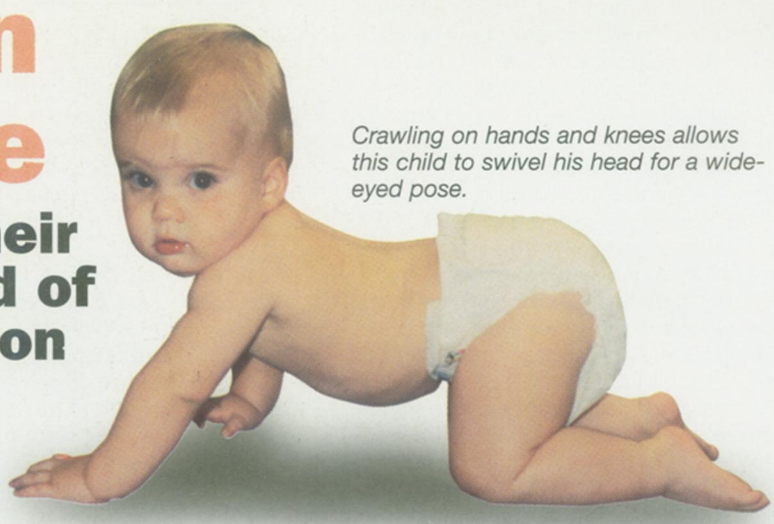
Minds on the Move

Babies extend their reach into a world of thought and action

By BRUCE BOWER



Crawling on hands and knees allows this child to swivel his head for a wide-eyed pose.

Photos: K. Adolph

Before they could stand on two feet or utter a single word, Gabriel and Hannah achieved a remarkable milestone in front of intrigued scientists. In a series of laboratory tests, each child improvised ways to reach out with one of their arms from a sitting position and wrap their fingers around a toy. In the process, they provided glimpses of the unique paths that infants blaze in coordinating their bodies and minds to function in their surroundings.

The babies' achievement may not sound too impressive to the average grabby adult. However, consider it from another perspective. Not long before, Gabriel and Hannah's parents had raved when the babies simply lifted their heads off a blanket or later rolled over.

Now, somehow, the two healthy babies had acquired the beginnings of the extraordinary limb control that their parents take for granted in, say, picking up a cup of coffee. This act, rendered routine through years of practice, requires first obtaining a three-dimensional view of the cup and estimating the spot where one's hand can grip it. Then comes the tricky business of hauling an entire arm through the air so that a few fingers can thread the cup's handle.

All sorts of split-second adjustments keep each reaching motion on course. Rapid arm extension requires holding the body steady so the arm and upper torso don't plow into the coffee cup. Muscles in the arm and shoulder contract and stretch in a host of combinations and exert a variety of forces. These arm movements are not exact, machine-like motions that can be precisely planned out in advance.

Despite challenges such as these, Gabriel, Hannah, and all the other babies studied by psychologist Esther Thelen of Indiana University in Bloomington begin at 3 to 6 months of age to snatch playthings placed in front of them. Thelen and her colleagues use what they call a dynamic systems approach to explain how kids master motor skills and perform an array of cognitive feats, including word learning (SN: 4/25/98, p. 268). This perspective represents, in their view, a sharp departure from most established scientific theories of the mind.

The dynamic systems approach rejects key notions long held by cognitive psychologists and motor-development researchers. Those scientists have proposed that a genetic code guides individual development through a progression of specified stages of movement and thinking. They assume that knowledge depends on a computerlike processing of symbols that are mental representations of the world and that nature operates separately from nurture, although the two often interact.

Instead, Thelen argues, a child's physical, mental, and social lives arise out of a shifting interplay between perception and action. General goals cherished by all babies, such as investigating novel items and putting anything available into the mouth, get the developmental ball rolling. As a youngster acts on these desires, the central nervous system, the rest of body, the immediate surroundings, and the task at hand together yield new insights and behaviors.

Dynamics refers to the reorganization that occurs as various players in this developmental symphony change their tunes.

Certain combinations of influences usually occur at specific times and yield common responses, such as the tendency of 3- to 6-month-old babies to reach out and grab interesting-looking things. Rapid changes in any of these influences, such as a child's body proportions, may cause a hard-won skill such as reaching or crawling to vanish temporarily or become disjointed, according to dynamic systems reckoning. Each period of flux ushers in a new phase of learning attuned to the realigned dynamic system.

No clear line separates innate from environmental contributions to success at reaching or any other developmental attainment, in this view.

Dynamic systems research examines skill learning over time with mathematical tools, borrowed from the physical sciences, for investigating how change occurs as many elements intermingle.

"From a dynamic point of view, the developmental questions are not what abilities or core knowledge infants and children really have or what parts of their behavior are truly genetic but how the parts cooperate to produce stability or engender change," Thelen says. "Reaching need not be predetermined [by genes or brain] because it arises as a solution to a goal within certain body constraints."

The Indiana psychologist would undoubtedly draw raised eyebrows from pioneer investigators of motor development. Between the 1920s and the 1940s, they meticulously catalogued age-appropriate stages of all sorts of behaviors, from rattle use to walking. Motor milestones such as these were theorized to depend on a genetically driven process of brain maturation.

Dynamic systems advocates draw much inspiration from the late Russian physiologist Nikolai Bernstein, who more than 30 years ago argued that subtle body changes in the first few years of life greatly influence movement and create new problems for the central nervous system.

Bernstein viewed motor development as a messy process. Thus, behavior does not grow more complex according to the regimented step-by-step orders of a neural commander.

Moving limbs are subject to gravity, and they must constantly adjust to the physical forces that they create, Bernstein held. They work much like springs, thanks to the placement of joints and the stretchiness of muscles. This allows a person to experiment with and refine limb movements, as with a baby's continual modification of arm speed and stiffness over many reaches.

Some refinements make more sense than others. Although legs can be used to hop, skip, and jump, people usually walk when moving from one place to another. Walking represents the best solution to the need to change location for a creature that stands upright and steps forward while maintaining contact with the ground, Bernstein argued.

This perspective provides a foundation for understanding how infants become reachers, Thelen says. She and her coworkers have intensively studied the 10 children seen in weekly laboratory sessions from age 3 weeks to 1 year.

The data analyzed so far indicate that infants achieve stable postures, in which they keep their head upright and coordinate head turns with arm motions, several weeks before they begin to reach out and grab objects, Thelen maintains. Given this ballast, they then work on bringing arm movements under control in a process that depends greatly on individual body size, body proportions, and energy levels.

Consider Gabriel and Hannah at 3 to 4 months of age. As they became able to sit up and turn their heads toward a conveniently placed toy, both children exhibited the spontaneous arm movements that serve as raw material for reaching. Both also seemed to want the toy and know where it was.

Each child, however, faced a distinctive challenge in controlling his or her springy arms. Before learning to reach, stocky Gabriel sat stiffly in an infant seat, thrust his head forward, and flapped his arms wildly as he anticipated presentation of a toy. Hannah was smaller and more composed, looking around carefully and making small hand movements while keeping her arms close to her body.

Gabriel had to slow down his flailing arms so that he could guide one of them toward the toy. Hannah, in contrast, needed the energy boost supplied by stiffening her muscles and extending her arm outward.

At age 15 weeks, Gabriel began to swat at toys at the end of his trademark flappings. Over the next few weeks, he started to slow down his arm as it approached the toy. But the tremendous force created by his shoulder-dominated flaps still created plenty of spring, and his hand followed a roundabout course to its destination.

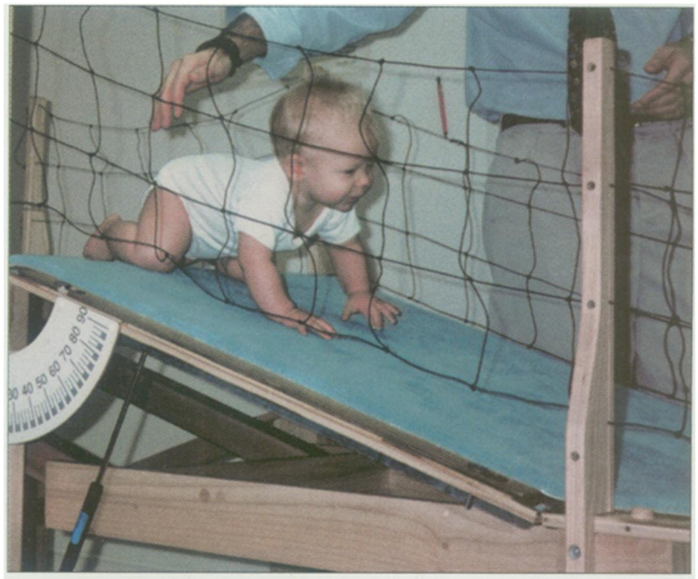
Hannah's cautious demeanor first yielded toy-directed reaches later than Gabriel's, at 22 weeks of age. From the start, Hannah sat completely still and then made slow, well-coordinated movements. She took longer to make hand contact with a toy after initiating a reach than Gabriel did, but her arm traveled a much smoother path.

Thelen described these findings last October at the 29th Carnegie Symposium on Cognition in Pittsburgh.

Gabriel and Hannah's adventures in reaching illustrate a fundamental, rather daunting aspect of motor development that is emphasized in the dynamic systems approach. When kids adopt a new posture—such as advancing from lying faceup to sitting or from a sitting to a crawling position—their world changes so much that they have to take a new course in body control.

Each posture invokes a particular kind of coordination between perception and action, says psychologist Karen E. Adolph of New York University. Sitting, crawling, and other positions involve different muscle groups, different patterns of coordination among limbs, different vantage points on one's surroundings, and different combinations of visual and sensory cues about balance.

Each new posture brings infants into contact with new facets of the world, from mobiles and blankets to doors and cabinets. The redesigned stances and bodies also inspire new goals. A novice toddler may have the two-legged revelation, for instance, that it's fun to trail the family dog around the living room in hopes of pulling its tail.



Babies who had learned the difference between safe and risky slopes as crawlers, top, had to educate themselves about slopes all over again as walkers, with the help of sure-handed chaperones.

"The developmental solution for acquiring adaptive [motor skills] in the midst of so much change may be the necessity for weeks and weeks of learning about balance control at each postural milestone," Adolph asserts.

When tracked closely over time, this type of learning exhibits much variability from one child to the next and looks nothing like a neat progression of stages, according to the New York researcher.

Crawling offers a prime example. A long-term study of 28 infants directed by Adolph, published in the October 1998 CHILD DEVELOPMENT, found that most displayed an array of crawling postures that did not emerge in any set pattern as they readied themselves to walk.

In particular, 15 youngsters crawled on their bellies for a month or more before crawling on hands and knees, whereas 13 skipped belly crawling and adopted a hands-and-knees posture at around the same time as the others.

Babies display a variety of crawling styles, Adolph says. Belly crawls included scraping the whole underside along the floor and, even more gymnastically, using the arms to push up on the knees and then belly flopping forward. In the more sophisticated crawling, some kids alternated the standard hands-and-knees gait with a bearlike crawl, in which they advanced on hands and feet.

Belly-crawling experience gave infants an initial leg up in coordinating hands-and-knees crawling, Adolph notes. Belly crawlers, however, did not walk earlier or more fluidly than the others, she says.

Infants also fail to carry knowledge about safe and risky modes of moving across sloped surfaces from one posture to the next. In experiments directed by Adolph, crawlers took a few weeks to learn to avoid or edge down steep slopes on an adjustable walkway, with an experimenter standing guard to catch those who began to tumble.

In their first week of walking, however, these children had to be rescued when they tried to traipse down dangerously steep slopes that they had come to avoid as crawlers. In their new, upright stance, they again took several weeks to distinguish safe from risky slopes.

A baby in Karen Adolph's lab does a fully prone "army crawl."

As these examples suggest, bodily interactions with the world produce mental and decision-making proficiencies as well as motor skills, Thelen asserts. More clues to the intertwined dynamics of knowing and acting come from studies of a curious error in reaching that many infants commit from about age 7 months to 1 year.

Indiana psychologist Linda B. Smith and her colleagues note that before 7 months of age, most infants refuse to look for a toy more than a few seconds after they've seen it being covered by a lid. After 1 year of age, they avidly search for toys hidden in this way. If they see a toy moved from one hiding place to another, they go for the appropriate lid.

For several in-between months, however, infants remove a lid if they initially see a toy hidden under it but refuse to look for the same toy if it's then openly moved to a nearby hiding place. Instead, they continue to pick up the first lid.

This poorly understood phenomenon has been dubbed the "A-not-B error." A number of researchers theorize that infants who misfire on this task realize where the toy lies—as evidenced by extended gazing at the new toy location—but cannot control their arms well enough to act on their knowledge. Others pin the problem on a poor memory combined with an immature brain that cannot yet inhibit practiced actions.

Thelen and Smith instead argue that a child's accurate memory of many correct reaches to the first lid literally pulls him or her back to that cover in the wake of a switch. All A-not-B experiments begin with training trials in which infants learn to search for toys at the A location, they note. In a new study, the Indiana scientists find that most 9-month-olds given no prior training either refuse to reach or pick up the wrong lid upon first seeing a toy hidden at the A location.

Moreover, infants who undergo training for the A location while sitting often reach correctly to location B after a switch if a parent holds them in a standing position to watch the hiding episode. This strategy disrupts the powerful memory of repeated reaches to location A, which was linked to the position of the hand and arm in relation to the hiding place, Thelen proposes.

Memories of a practiced arm reach may sometimes defer to attention-grabbing features of a new hiding spot, she adds. In other experiments, for instance, 9-month-olds usually pick location B if they see cookies hidden there rather than a toy.

"The A-not-B error appears as part of a continuum of developmental changes affecting reaching, looking, remembering, and planning for action," Thelen remarks.

It's unclear whether cognitive scientists will reach for and remember the Indiana psychologist's perspective. For instance, Nick Chater of the University of Warwick in Coventry, England, dismisses dynamic systems work as largely bereft of any specific proposals about how minds work. Computation theories of how brains process information offer far greater potential for unraveling the mechanisms of thought, he asserts.

Andy Clark of Washington University in St. Louis, however, finds value in integrating Thelen's focus on developmental changes in thinking with the mainstream study of stable mental operations, such as those devoted to memory and perception.

In contrast, Benny Shannon of the Hebrew University of Jerusalem views dynamic systems theory as a cut above cognitive science's emphasis on static mental representations. Like connectionist computer programs that acquire linguistic and other skills without following preset rules, Thelen's approach suggests that mental activity must be studied as it unfolds over time, Shannon holds.

Thelen agrees. "I think the next generation of scientists will be more comfortable with the notion that cognition is not symbolic and computational."

In true dynamic systems fashion, she'll wait and see what develops. □