A Life Span Concept of Motor Development

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A concept of life span motor development is presented. Evolution of the author's concept of motor development is traced from its beginnings in classic developmental theory rooted in the biological sciences. Influenced by contemporary motor control theory and the writings of Milani-Comparetti, mechanistic models of nervous system function were abandoned in favor of active organism concepts. Application of classic developmental theory to the practice of physical therapy led to a specific focus on righting behaviors and eventual discovery of the limitation of classical neurodevelopmental theory for the explanation of adult motor behaviors. The author's current research focus is summarized; it was formulated from a perspective of lifelong development and is directed toward describing age related movement patterns in a series of righting tasks.

Motor development is a lifelong process of age related change in motor behavior. This ongoing process is brought about by the interaction between the individual's constitution and environment, both of which are also undergoing dynamic change. A life span theory of motor development presents a different scale and breadth of concern than do traditional concepts associated with development of motor abilities during infancy and childhood. Life span theory embraces the seemingly obvious changes in organization of the neuromotor system accompanying dramatic changes in size and body form during infancy, childhood, and adolescence—the subtle changes of young adults entering and leaving active lifestyles as a result of school, work, and family responsibilities; the use of earned leisure time by older adults to participate in sport and fitness activities or to work with their hands in crafts.

In my view, maturity, which is the traditional marker of the completion of developmental processes, is nothing more than a fleeting moment in developmental time. To me maturity is an instantaneous and somewhat arbitrary standard of completion of certain growth processes. It is valued too much and is a standard against which younger and older individuals are often inappropriately compared. To use the traditional concept that maturity is attained in young adulthood and is the end state of development would exclude more than two thirds of the human life span from legitimate developmental study. From a life span perspective, I

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value maturity no more than infancy, old age, or transition from Step 2 to Step 3 of a developmental sequence. Age related changes in motor behavior occur throughout the life span, and all these changes have something to teach about the developmental process.

A life span perspective, while not bringing novel explanatory constructs to the study of developmental processes, does help put circumscribed and microscopic explanations of developmental processes into a broader framework of analysis. The life span concept brings power to our understanding of age related change in motor behavior. It is a reminder that some processes of change might be unique to specific but universal life periods, and that some processes of change affected by changing societal variables may influence the motor skills of some cohorts but not others. For example, the rate of growth during infancy may explain some change in behavior early in the life span and instruct us regarding change processes that occur during later growth spurts in childhood and adolescence. Rate of growth as a change parameter, however, may not clarify change processes that occur during the middle years of adulthood.

On the other hand, the current concern for health and fitness may well have widespread impact on the motor behavior of those now entering middle and later adulthood, but little impact on those in primary school. Likewise, a surging interest in soccer among middle-class schoolchildren and the love affair with joy-stick-controlled home video games are also examples of trends that may well affect motor developmental processes of specific cohorts.

As we grow and age, the body on which we rely for expression of our motor abilities changes. Flexibility and muscle performance change, and the nervous system and its peripheral sensory end organs also change. The constitutional or biological substrate for skills is not stable across time. And as we age, the environment in which we live also changes. The improved health status afforded us compared to previous generations demands a fluid understanding of developmental processes. It is this instability of environments and individuals that is the dynamic and true nature of development. We are variable by nature and so are our environments. Interaction among internal and external sources of variation, when operating systematically over time, produces age related change. It is this systematic age related variability in its many dimensions that is the expression of motor development.

Evolution of My Life Span Concept of Motor Development

My concept of motor development has evolved over time: the result of ideas gathered from many individuals and during many periods of my life. My first encounter with motor development as a scholarly topic was as a physical therapy student reading McGraw's classic *Neuromuscular Maturation of the Human Infant*. Prior to this exposure to McGraw, I had completed courses in human anatomy, kinesiology, and neuroanatomy. Neuroanatomy lectures, taught by a neurosurgeon, were laced with examples of pathokinesiology. Demonstrations of hemiplegic gait and cerebellar ataxia, for example, helped cement my understanding of the relationships between brain structures and bodily movements. With these core biological sciences as a background, the thesis of McGraw's work was quite logical. Her descriptions of infant motor behavior were so clear, and her
purpose that sought to assign specific developmental changes in behavior to maturation of specific cortical areas seemed to make intuitive sense.

What happened in that initial exposure was my discovery and unwitting adoption of classic developmental theory rooted in biological science: early appearing motor behavior was automatic and reflexive. Gradually throughout the course of the first year of life, the cortex of the brain matured and exerted control over reflexes enabling the infant to produce volitional purposeful action. Reflex integration as a fundamental process of development had been firmly embedded in my mind and I could produce a few examples from McGraw’s work to support the premise.

For me the reflex became the basic functional unit of neural organization. The reflex as a theoretical construct was also imbedded in the classic model of motor control introduced in my subsequent course in neurophysiology. The reflex was such an integral part of these models that, for me, it became real.

The motor control model was a reflex hierarchy composed of phasic spinal reflexes, including the flexor withdraw, stretch, extensor thrust, and crossed extension reflexes. These phasic reflexes were controlled by the tonic postural reflexes of the superimposed brainstem. Brainstem reflexes were under the mediating influence of the midbrain righting reactions, which were integrated by high level cortically originating equilibrium reactions. But the model was more than a model of motor control.

Rich evolutionary and developmental concepts are associated with this catalog of reflexes. Within the hierarchy is a blending of the simpler reflexes, classified as phasic movements and tonic postures, into the more complex “postural movements” of righting behaviors. Righting reactions turn crude brainstem postural reactions to sophisticated orienting movements of the head and body with respect to the environment. The reflex hierarchy is a fertile conceptual model, and from a contemporary perspective it is an extremely useful framework for beginning students of motor development. For a physical therapy student this model also serves as a foundation for pathokinesiology of neurologic disorders. Regression to lower levels of the hierarchy under pathological conditions is a well accepted tenet of clinical neurology.

Treatment theories developed by physical therapists whom I was to encounter were influenced by the work of McGraw (1963), Gesell (1940), and other biologically based neuromotor developmentalists such as Coghill (1964), Hooker (1958), and Twitchell (1965). For physical therapists, fetal and primitive reflexes serve as a basis for understanding the pathokinesiology of disorders such as cerebral palsy, head injury, and stroke. The theories of Rood (Stockmeyer, 1967, 1972), the Bobaths (Bobath, 1965; Bobath & Bobath, 1972), and Knott and Voss (1968) incorporated ideas gleaned from classic studies of motor development and compatible concepts of neuromotor control. The developmental sequence represented the natural plan for acquiring the very fundamental motor skills such as rolling over, sitting up, creeping, standing, and walking. This sequence commonly became the treatment plan for persons with neurologic or developmental disorders, regardless of age. Even elderly individuals following a stroke were taught in successive order to roll, then sit, then creep, and finally to stand and walk.

Berta Bobath was a strong influence on my understanding of the development of infant movement. During an 8-week training course, I watched her demonstrate the movements of infants acquiring the rolling, sitting, creeping, standing, and walking tasks. Study of photographic essays of infants and children in motion
and laboratory sessions involved observation of normally developing infants as well as infants and children with cerebral palsy. As students we were expected to recall the form and sequence of action that took the normally developing infants from one stable posture to another. We practiced movement in tasks such as sitting up and rolling from back to stomach. These laboratory experiences were accompanied by required readings of the original neurological research literature describing the reflexes and their development. This literature included articles by Weisz (1938) on equilibrium reactions, Schaltenbrand (1928) on righting reactions, Magnus (1926) on tonic reflexes, and Sherrington (1947) on spinal reflex mechanisms.

It was in this clinical laboratory setting that I began to develop a fascination for the form of righting reactions. Righting comprises the set of motor behaviors that enable one to move from one stable body posture to another, and to align the head and major body segments with respect to gravity, the visual surround, and to neighboring body segments. In righting behaviors, posture and movement blend in a harmonious interplay allowing the functional action of daily life. Closely allied with balance or equilibrium reactions, righting behaviors such as balance reactions rely on vestibular, visual, and somatosensory information.

Righting reactions can be differentiated from equilibrium reactions. Righting involves movement from one stable postural configuration to another: rolling from back to stomach, moving from back lying to sitting, moving from kneeling to standing, and so forth. The ultimate purpose of righting behaviors is to bring the body to an upright posture against the prevailing force of gravity, regardless of the start position. Equilibrium reactions, on the other hand, preserve and maintain the current posture of the body statically and dynamically. For example, equilibrium reactions operate to maintain upright posture during a static task of maintaining a one-legged standing posture, or during single-limb support in locomotor tasks such as walking or running.

Singular in purpose, righting reactions are variable in form. The variability in the form of righting behaviors was the element that sparked my interest. Originally I only noticed how various start positions affected the form of righting behaviors. Under Bobath’s guidance we practiced moving from one posture to another, varying the start position and keeping the end position constant. We then performed righting tasks from a single start position to various end positions. Noticing interindividual variation when the start position was similar, we speculated on why individuals differed from one another, particularly young, healthy, mature adults. The answer, quite traditional and predictable, was, “As fully mature young adults, we could voluntarily move any way we wished.”

The issue of variability in forms of righting could be explained by reference to the start position and a tenet of neurophysiology: von Uexkull’s law (von Uexkull, 1905/1970). Also known as the law of Magnus, this law declares that the brain registers the state of the body musculature; the state of elongation and contraction of muscles determines subsequent action. When von Uexkull’s law did not accurately predict behavior, we resorted to an explanation of variable forms of action based on the individual’s will, or volition. We did not venture beyond these traditional confines.

The reflexes and volition, rather than theoretical constructs, had become quite real, like bricks in a wall of thinking. But my views of the developmental process were about to change drastically, for there were far too many instances when reflexes and volition were inadequate and inappropriate explanations of the behavioral manifestations of neural function.
In 1976 I attended a symposium on the neural control of locomotion. This conference brought together an international group of scientists who had been working to elucidate the characteristics of spinal pattern generators as elements of locomotor control in both vertebrate and invertebrate species. Papers presented at this conference (Davis, 1976; Edgerton, Grillner, Sjostrom, & Zangger, 1976; Forssberg, Grillner, Rossignol, & Wallen, 1976) were to influence my thinking over the next several years. It was this encounter with the notion of “self-generated” action as an integral part of spinal physiology, and my first exposure to a heterarchical model of motor control (Davis, 1976), that was to spark a new understanding of motor control and development.

Soon after that conference I was exposed to the ideas and teachings of another developmentalist: Dr. Milani-Comparetti, an Italian neuropsychiatrist, had become well known in the pediatric physical therapy community for his article on “Routine Developmental Evaluation” (Milani-Comparetti & Gidoni, 1967). Within that screening program, Milani-Comparetti emphasized the relationship between integration of postural reflexes and reactions and the accomplishment of the traditional developmental motor milestones of infancy.

During a lecture visit to the United States in 1979, Milani spoke of his just completed review and interpretation (Milani-Comparetti, 1981) of the ultrasonographic data from a study of fetal movements (Ianniruberto & Tajani, 1981) that had yet to be published. As a result of his study of fetal movements, he had developed a very different concept of development. After reviewing the fetal movements recorded from more than 1,000 normal pregnancies, he became convinced that the fetus generated its own action early in the course of prenatal motor development. This self-generated activity was observed prior to the development of responsiveness. Stimuli that would elicit action as reflexive responses were not evident in the natural fetal environment exposed by ultrasonography, and there were no clear relationships between sensory events and motor behaviors during the early fetal period.

Having been exposed to the idea of a spinal pattern generator at the 1976 conference on neural control of locomotion, I was eager to explore these concepts from a developmental perspective. The notion of the fetus as an active organism was not unthinkable, despite my previous understanding of predominant and traditional accounts of fetal behavior as purely reflexive in nature (Fitzgerald & Windle, 1942; Hooker, 1958).

Milani-Comparetti, having cast away reflexes as the building blocks of motor behavior, made reference to what he termed primary motor patterns (PMPs). In his view, PMPs served as the fundamental unit of neuromotor organization. They comprised the neurologic substrate for observable spontaneous behavior early in the course of fetal development. The fetus in Milani-Comparetti’s view actively generated PMPs. Although he went on to present a new theory of developmental pathokinesiology, most who heard his lectures were struck with his presentation of a new concept of fetal behavior: that of acknowledging the fetus as an active organism.

The PMP, an embedded construct in Milani-Comparetti’s theory, initially was not fully appreciated. PMPs, though producing stereotypic behavior, were not necessarily bound to specific sensory events (stimuli) and therefore were a more versatile unit of behavior. PMPs could be self-generated, either through spontaneous unconscious processes or through willful and conscious processes. Or PMPs could be evoked by external sensory influences. Furthermore, PMPs varied systematically with age.
The idea of a motor pattern, or motor synergy, has long-standing status in neurologically based theories of physical therapy (Bobath, 1965; Brunnstrom, 1970; Fay, 1955; Knott & Voss, 1968; Stockmeyer, 1967). Although Easton’s (1972) paper stimulated renewed interest in the idea of motor patterns as a structure of CNS organization, this had been an enduring theme for therapists treating individuals with neurologic and developmental disabilities. The axiom that “nervous centres know nothing of muscles, they only know of movements” is a classic tenet for these therapists. It is the idea of muscles working in patterns that sets neurodevelopmental theories apart from their biomechanical competitors in offering explanations of abnormal motor behavior. Neurodevelopmentalists explain disordered posture and movement as abnormalities of motor patterns. Normal motor patterns and synergies are the content of physical therapy for individuals with neurologic dysfunction.

It was in the discovery of the body of literature generated by the motor development laboratory at the University of Wisconsin-Madison that I found a kindred concern for motor patterns. As a physical therapist, my concept of development had been formed predominantly in regard to such primary motor skills as rolling over (from back to stomach and stomach to back), sitting up, getting onto all fours, rising to kneeling and half kneeling, and then to standing and walking.

To my delight, the Wisconsin group had been involved over an extended period of time in identifying developmental sequences of movement patterns for such unexpected tasks as jumping (Hellebrandt, Rarick, Glassow, & Carns, 1961) and the overarm throw (Roberton, 1978). Furthermore, there was a whole body of literature describing the development of fundamental motor patterns (Wickstrom, 1977), and with this discovery came validation of the idea that identification of basic movement patterns is a critical step for the study of human movement.

As a therapist I had somehow thought the age related processes of movement pattern change were only applicable to tasks that evolved during the first year of life. I had not much thought about the natural forms of throwing and jumping. The idea that the form of throwing movements might be age related provided a fresh perspective to my thinking. I began to consider the idea that the patterns of movements used to perform a wide range of tasks might be age related. Variability in form could have a developmental base for tasks other than those acquired during infancy.

I found Roberton’s (1977) report of her development of the component approach to description of body action another rich source of hypotheses concerning the developmental process. I had previously read the work of Lawrence and Kuypers (1968a, 1968b) which provides evidence for separate descending neuromotor control systems for different body regions of primates. I saw the possible applicability of the component approach to movement description to the study of movement pattern development within body regions selected to coincide with Lawrence and Kuypers’ (1968a, 1968b) model of descending neuromotor control. By studying the axial region of the body and the arms and legs as separate components, it would be possible to examine developmental relationships among them including the process of differentiation of extremity and axial movement patterns.

The opportunity to study in the motor development laboratory at the University of Wisconsin was a life event. It was there, after nearly 15 years of working in the medical community, that I became aware of the rich resources in the social sciences. In formal courses I was exposed to life span developmental theory and underwent another revolution in thinking about motor development. I could no longer contemplate developmental processes without examining the premise that the characteristics of age related change may or may not be similar during all phases of the human life span. In addition, I read Anokhin’s (1964) writings on systemogenesis and saw similarities between his ideas and Milani-Comparetta’s (1981) theoretical stance, both of which shared themes with Davis’ (1976) presentation of a systems model of neural control.

Looking back across the literature that so strongly influenced my thinking, I am aware of a repetitive theme: motor patterns vary with age. This idea was evident in McGraw’s (1963) work, in Schaltenbrand’s description of the development of righting reactions, in Milani-Comparetta’s work, and in the body of literature generated through the University of Wisconsin’s motor development laboratory.

The description of motor patterns as a qualitative aspect of motor behavior, and documentation of the developmental coming and going of these patterns across the life span, became my primary interest. Beginning in Wisconsin under the direction of Lolas Halverson, and continuing to the present, my students and I have started to identify and describe motor patterns used to perform those very primary motor skills that our physical therapy colleagues must teach to disabled individuals.

I first undertook a study of a righting behavior in my dissertation research: the task of rising to standing from supine lying on a floor mat (VanSant, 1988a). I had hoped to describe the movement patterns used to perform the task and propose developmental sequences for three components of body action. I adopted the assumptions of stage theory as applied to motor development (Roberton, 1977) for this initial study of a single age group of young adults, my reasoning being that if age related change in motor behavior occurs across the life span, then one is not limited to studying children to identify developmental sequences.

After describing the movement patterns, I used the adjacency criterion to order the movement patterns into what I proposed as developmental sequences for each of the three body components. I then performed a cross-sectional screening (Roberton, Williams, & Langendorfer, 1980) of the proposed sequences using a group of young children (VanSant, 1988b). While studying children’s performance in the rising task, I identified two additional movement patterns that were not evident in the behavior of the young adults and formalized description of one movement pattern, a pattern that until then I had observed in only one adult but that was relatively common in young children.

We have gone on to study additional righting tasks including rolling, rising from a bed, and rising from a chair. Generally we first describe movement patterns and propose sequences using a single age group of young adults (Richter, VanSant, & Newton, 1989; Sarnacki, 1985) and then screen our proposed sequences in both older (Ford-Smith, 1989; Luehring, 1989; VanSant et al., 1988) and younger age groups (Boucher, 1988; Lewis, 1987; McCoy, 1989; Sabourin, 1989). Our goal is to identify age related differences in movement patterns for a set of primary functional motor tasks.

After a relatively intense period of research, I have become convinced of the value of studying young adults as the first step in identifying developmental sequences of movement patterns. From a very practical standpoint, this segment
of the human population is much more accessible to the academic researcher than are younger or older groups. Although it is likely that not all movement patterns used to perform a task will be observed in young adults, I now expect only those patterns specific to the very young or elderly individuals to be absent in this age group. And, no less important, using young adults to identify movement patterns that we are consistently demonstrating to be age related reminds the skeptics that motor development is not a process exclusive to infancy, childhood, and adolescence.

We are discovering that not all movement patterns are developmental steps. Although the capacity to perform nondevelopmental movement patterns might rest upon age related factors, the appearance of such patterns seems more related to performance factors than to age. For example, in the task of rising from the floor, very few individuals (3 of approximately 350 subjects) did not use their arms to push against the surface. In using a distinctive form of arm action that is easily described and categorized, it appears the subjects are challenging themselves to get up without using their arms. We have seen this pattern when individuals rise from the floor or from the bed. A somewhat similar arm pattern has been observed in two subjects performing the task of rising from a bed (McCoy, 1989).

We have graphed the incidence of each movement pattern by age group. For the task of rising from the floor, a pattern of developmental progression is evident, followed by regression in which the last pattern to predominate is succeeded by its predecessor (VanSant, in press). This simple model of progression and regression of patterns, consistent across all components of the task of rising from the floor, is not the case for all tasks we have studied. In the rolling task, some patterns predominate more than once without demonstrating a consistent relationship to preceding or succeeding patterns. The complexity—the specificity and the apparent sequences of development—is in itself inducement to continue our work. And we still have to examine the relationships among the components and their stability or variability with respect to age.

As a result of all this, I no longer see motor development as a hierarchical process dependent upon those more elemental bases that were laid down previously. Rather, development has become a process of dynamic organization and reorganization of motor behaviors into what I view as labile hierarchies, each formed in the context of a biological substrate that changes over time and environments that change over time. I now see motor behaviors forming and reforming to meet the needs of the individual in the real context of his or her environment—motor behaviors forming and reforming from a fundamental set of motor patterns that also undergo age related change across the entire spectrum of one’s life. While others seek the cause of motor development, I prefer to describe its expression in the motor patterns of individuals of all ages.

References


