

A Dynamic Systems Approach to the Development of Cognition and Action

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Life, said the English novelist Samuel Butler, is like giving a concert on the violin while learning to play the instrument. Butler's insight-that there are no distinct training and performance modes in development - succinctly captures the activity-dependent nature of the developmental process. For example, imagine a baby learning to walk. Although babies spend a great deal of time failing down, getting up, and falling down again, as far as some parents are concerned, their child's walking seems to magically appear de novo one day. Other parents, however, do appreciate the importance of their baby's ups and downs and believe the old saying that "practice makes perfect" in the emergence of walking. Butler's insight, however, suggests a third perspective on the emergence of such novel behavior: namely, that there are no practice modes in development-all activity counts in selecting, constructing, and maintaining behavioral outcomes. This fundamental role that self-generated activity plays in the development of all behavioral functions, ranging from motor behavior to perception, cognition, and social behavior, is a central theme of the dynamic systems approach that is masterfully explicated in the recent book by Esther Thelen and Linda B. Smith. In this book the authors (both developmental psychologists) apply the principles of nonlinear dynamic systems to motor, perceptual, and cognitive development and the result is a remarkable synthesis and advancement of developmental science. Indeed, it would not be an exaggeration to say that this volume offers a revolutionary perspective on the development of cognition and action.

According to Thelen and Smith the primary thrust of development is the generation of novel structure and behavior. In their attempts to explain this complex process, Thelen and Smith eschew the classic dualisms of structure vs. function, nature vs. nurture, brain vs. behavior, perception vs. cognition, mind vs. body, competence vs. performance, and learning vs. development. Their rejection of dualistic thinking results in a radical departure from current cognitive theory and provides a view of development in which stability and change are accommodated under a single theoretical umbrella. This umbrella, of course, is dynamic systems theory, an approach that is doubtlessly familiar to many of the readers of this journal. What makes this book different from other books on the topic of dynamic systems, and more useful than many in this genre, is both its breadth and its explicit focus on the developmental processes underlying the emergence of motor, perceptual, and cognitive functions. Indeed, we believe Thelen and Smith's book is unique in this area in that it provides multiple examples of the successful application of the dynamic systems approach to the study of human development as well as a methodological agenda for the generation of new research programs.

Thelen and Smith begin their book by discussing the shortcomings of many of the major theoretical systems associated with the study of human development (e.g., maturationist, neurological, rationalist-nativist, and information processing) and note that all of these approaches have a common teleological core that implicitly presumes an "end-state" before the developmental process even begins. The authors then go on to reject simple

cause-and-effect models that rely on predeterminism, linearity, and reductionism. In their place, they offer a comprehensive approach to the development of behavior that focuses on the processes underlying change in dynamic, self-organizing systems. These systems have a history, can create novelty out of contextual and organismic conditions, and do not have an "end-state" coded anywhere. The early chapters of the book are organized to showcase the authors' own research programs on early motor (Thelen) and cognitive (Smith) development to illustrate the explanatory power of this approach for complex behavioral phenomena. In these chapters the authors also utilize the power of their approach to show how previous interpretations of findings in these research areas are misguided in relying on concepts of innate programs or innate knowledge structures.

In subsequent chapters Thelen and Smith address the relation between morphology, neural processes, and behavior in promoting developmental change. In relating these three, the authors rely heavily on N. A. Bernstein's (1967) concept of indeterminacy and Gerald Edelman's (1987) concepts of selection and reentry (the interrelating of several or many simultaneous perceptual and motor representations) to provide the means by which novel neural and behavioral structures and functions may be "soft-assembled" in real and developmental time. Of particular interest to the readers of this journal is the authors' argument that the dynamics of behavioral phenomena and the known dynamics of neural phenomena should be consistent with one another. Most importantly, Thelen and Smith argue that a reductionistic approach that resorts to interpretations based solely on neural factors leads to infinite regress in our explanations of the process of the emergence of novel structure and behavior. In their dynamic systems approach, the neural aspects of human functioning are part-and-parcel of the individual's entire developmental system. No single element or level in this system necessarily has causal primacy or privilege. Indeed, Thelen and Smith's approach to development virtually requires that equal status be given to all contributing factors at all levels of analysis.

A central question for students of perceptual and cognitive development is how perceptual categories, which are the foundation of human cognition and action, emerge during development. What are the processes and mechanisms that allow meaning to be assigned to the multiple and continuous sensations of everyday life? Thelen and Smith devote a major section of the book to a discussion of this question and propose that the answer must lie in (1) the recognition of the fundamental unity of perception and action and (2) the critical importance of the temporal association of multimodal information in creating the link between the mind and the world. In their active exploration of the world, infants receive massive amounts of time-locked, multimodal sensations. The authors argue that infants discover action and object categories through the cross-correlation of these multimodal experiences. In their own words, "what infants know and how they act are selected continuously and dynamically from what they encounter and how they act. Sensory integration is the primitive, not the derived state, and knowledge is limited not primarily by deficits in storage but in the ability to adequately sample and thus categorize the world" (p. 211). This position obviously challenges much contemporary work in the field of cognitive development and will likely engender controversy among students of cognition.

In the remaining chapters of the book Thelen and Smith discuss and explain developmental phenomena as diverse as memory, traversing slopes, word knowledge, reaching, and the A-not-B error within the dynamic systems framework. For example, Thelen and Smith demonstrate the value of dynamic systems principles in explaining the development of reaching in human infants. They show through the detailed longitudinal study of individual infants' performance how different babies arrive at very different solutions to the common problem of retrieving an object. Through detailed examination of the day-to-day variations in arm movements, the authors convincingly demonstrate the unique developmental pathways that different infants utilize in their eventual solution to the problem of reaching. By doing so, Thelen and Smith elucidate the distinctive, context-dependent, and self-organized nature of development. In their own words, the "solutions were discovered in relation to their own situations, carved out of their individual landscapes, and not prefigured by a synergy known ahead by the brain or the genes" (p. 260).

Thelen and Smith conclude the book with a considered look at the "hard problems" facing contemporary developmental science. In their opinion, one of the key unresolved areas is the traditionally thorny issue of value and motivation. In their discussion they resurrect the important but often overlooked contributions of Kurt Lewin, who recognized the significance of a systems approach to behavior over half a century ago. In particular, Lewin focused on the central role of value and motivation in directing developmental change. Similarly, the concept of value is also very important to Thelen and Smith's dynamic systems theory because it provides a primary mechanism by which perceptual categorization is achieved. Value provides the motivational impetus for the organism to seek certain forms of stimulation and not others. Thus, very early in development, infants might be biased to seek contact or warmth, prefer light over dark, seek objects that can be sucked or touched, etc. Once objects or events that are preferred are encountered, different properties of these objects or events can then be differentiated through recurrent experience. According to Thelen and Smith, infants come into the world with a set of values or hedonic valences and the authors suggest that such values are somehow epigenetically acquired. What the authors do not offer, however, is a mechanism by which epigenetic forces confer positive or negative valence on particular forms of stimulation.

One such possible mechanism was proposed decades ago by the comparative psychologist T. C. Schneirla (1959). After reviewing the behavioral responsiveness and organization of young animals across different phyletic levels, Schneirla noted that the earliest forms of behavior in developing organisms consist of approach and withdrawal reactions. He proposed that the principal factor that accounted for these approach/withdrawal reactions was the effective intensity of stimulation (i.e., the overall level of stimulation engendered by factors internal and external to the organism). He noted that when the effective intensity of stimulation is low, organisms typically approach the source of stimulation, whereas when the effective intensity of stimulation is high, organisms typically withdraw. Very important to this notion of approach/withdrawal is that it is a noncognitive construct that does not imply prior knowledge of stimuli or their potential consequences. What Schneirla's theory offers to

Thelen and Smith's dynamic systems approach is a metric for predicting levels of sensory stimulation that will either have positive or negative valence based on the specific level of effective intensity. In other words, we believe approach/withdrawal theory offers a means to operationalize value and its role in the developmental origins of initial perceptual categorizations.

As this necessarily brief review attests, the range of issues and phenomena covered in this extraordinary book is extensive. At the same time, a striking feature of this book is its thematic cohesion and integration across diverse disciplines and levels of analysis. The authors have obviously labored long and hard to make it possible for the reader to critically consider complex and abstract issues. They also have provided a companion volume of edited chapters (Smith & Thelen, *A Dynamic Systems Approach to Development: Applications*, MIT Press, 1993) in which these issues are considered in the context of specific research programs. The publisher (MIT Press) of this volume, as well as the companion volume, has done a laudable job in producing an attractive book of high quality.

In sum, perhaps the highest praise we can give Thelen and Smith's most recent book is to confess that we both found ourselves being transformed intellectually in the process of reading it. Nearly every page required us to reflect on, reconsider, and in some cases reformulate our varied assumptions and viewpoints about the process of development. We sincerely hope that this book receives the wide readership that it deserves and in doing so helps to realize the revolution in developmental science it argues for.

REFERENCES

Bernstein, N. (1967). *Coordination and regulation of movements*. New York: Pergamon Press.

Edelman, G. M. (1987). *Neural Darwinism*. New York: Basic Books.

Schneirla, T C. (1959). An evolutionary and developmental theory of biphasic processes underlying approach and withdrawal. In Jones, M. R. (ed.) *Nebraska symposium on motivation*. Lincoln: University of Nebraska Press, pp. 1-42.