

Book Reviews


Here is a book that is addressed to a rather small audience—researchers on child development in the first couple of years—which is nevertheless accessible to, and I believe important for, a much larger readership. It is a serious attempt to apply to psychology a recent scientific development variously known as chaos theory, nonlinear systems dynamics, and the sciences of complexity. It is the first book on this development that I have been able to follow and absorb, despite my relative unfamiliarity with the technical literature of infant development. I strongly recommend it, therefore, to behavioral scientists who do not have strong grounding in mathematics and have been fascinated by chaos theories without being able to grasp how to apply them to their own work.

The authors are both professors of psychology and cognitive science at Indiana University and active contributors to empirical research. Thelen concentrates mainly on the attainment of locomotion and other forms of movement, while Smith's specialty is linguistic development. One of the beauties of the book is the way in which the reader comes to see how the same principles are applicable to both fields and indeed how inseparable cognition and action are.

Three sections make up the book. It begins with a general presentation of the dynamic approach as compared to other, prevailing viewpoints in developmental psychology. In the first chapter, however, the issues are given concrete form in terms of research on how babies learn to walk. Chapter 2 addresses most of the same topics but with a cognitive focus. The authors argue persuasively that here is a crisis in developmental psychology, none of the prevalent theories being able to account for many accumulating data. Their proposed solution, which they call the 'dynamic systems approach' (hereafter, DSA, an abbreviation Thelen and Smith do not use) is introduced in the third chapter, and then applied in Chapter 4 to the ontogeny of walking.

Part two, comprising three chapters, introduces Gerald Edelman's theory of neuronal group selection in an attempt to ground psychological observations in a explicit conception of the dynamics and embryology of the brain. It includes a discussion of the fundamental problem of categories (classification or concept formation) and how they develop through simultaneous perceiving and acting. This perception-action unity is basic also to the growth of learning and memory in infants, in what Thelen and Smith call 'real and developmental time' alike, whether we are talking about observations over minutes or months.

The final section, made up of Chapters 8–11, applies the DSA to many of the major puzzles of development, again with extended reference to data, both the authors' own and those of others. The final chapter outlines possible solutions to some of the most difficult problems of the field, in the areas of motivation and higher cognitive processes.

An ambitious program indeed! A great strength of the book is its constant turning from trenchant critique to clear exposition of difficult dynamic concepts, finally applying them to the details of concrete experiments. The authors have not solved all the problems of their field, but they have shown the considerable usefulness of their new approach in suggesting fresh empirical approaches to old problems.

The DSA evidently is an outgrowth of general systems theory (GST), and the authors acknowledge 'many similarities', noting that 'Developmental data are interpretable only with systems principles which stress wholeness, self-organization, nonlinearity, developmental buffering or equifinality, and hierarchical levels of organization' (p. xx). They allude only to von Bertalanffy and Laszlo, however, notably failing to mention Miller's living systems theory and its treatment of development. Their neglect of GST may be because too many authors invoke it only post hoc and have not translated it into 'empirical studies of developmental process' (ibid., their emphasis).

At the heart of the sophisticated critique of current developmental theories that follows is the observation that many of them, 'maturationalist, neurological, rationalist-nativist, and information processing, have a teleological core. This core presumes an end-state before the developmental process begins' (p. 49). In a way, it is a secular example of the argument from design for the existence of God: if there is orderly pattern, there must be a pattern-maker following some plan. Even Kenneth Boulding (1978) argues that any movement towards more complex and improbable structures must involve plans or 'know-how'. That, of course, leaves unexplained...
how the plan itself could have come into being without the intercession of a divine Planner.

One beauty of chaos theory is that it accounts for the emergence of novel pattern without prior plan, via self-organization. Natural systems of great variety, from the mixture of a couple of chemicals in the Belousov–Zhabotinskii reaction to the realm of human cognition, all organize themselves. Biological systems have the basic requirements of being complex and open: stable but far from thermal equilibrium, because energy flows through them. As Bronowski (1972)—another author not cited in this book)—put it, if they are perturbed by the influx of enough energy all systems are capable of being rearranged in many configurations, most of which are not viable and fall apart, but some of which do cohere. Moreover, a series of such stable states may exist at increasing levels of complexity, a fact Platt (1970) called hierarchical restructuring.

In the two decades since these pioneering papers, a great deal of detailed information has accumulated about just how the process of self-organization in natural systems comes about. If an open system is ‘complex, heterogeneous, and noisy’ it ‘has an enormous amount of potential behavioral variability’ (p. 55). Without a certain amount of chaos, a system would be too sedately stable to develop; with it, the system can find another stable mode, generally at a higher level of complexity. The process is driven by a source of energy called an order parameter.

Thelen and Smith adopt the colourful way of referring to this process favored by chaos theorists: the naturally occurring modes of stable organization are called attractors, and they are often represented as valleys on a metaphorical landscape. A system ‘seeking’ a stable mode is depicted as a ball rolling down a hill from a plateau; when it is on a flat area between two valleys, only a slight perturbation will make it roll into a concave space from which it may be dislodged only by a much more vigorous input of energy. The sequence of observed phase changes as an organism develops may thus be represented as a series of such valleys on an abstract landscape.

Such figurative language and diagrams help the neophyte grasp the basic ideas, but they bring along some dangers of which Thelen and Smith do not seem to be particularly aware. It is easy to get the misleading impression that a figure depicting an attractor results from mathematical operations or is itself a mathematical representation, or that it constitutes an explanation of some observed facts. There is also the danger of taking figurative expressions literally. A strange attractor does not actively draw anything to it in the way a magnet attracts iron; a system does not seek stability in the way that a lover seeks his beloved. Because certain of the possible configurations of a system are stable, when perturbed it ends up in one of them as if they were attractive or as if it was looking for them. It would have avoided confusion if the authors had pointed out these pitfalls more explicitly and had made less use of metaphorical expressions like ‘attractors’ and ‘valleys’ as if they were explanatory.

An admirable feature of this book is that Thelen and Smith consistently refrain from calling their DSA a theory. They say frankly enough that their approach is qualitative and non-mathematical, even though they hold out the hope that eventually it may prove possible to get clean enough quantitative data to permit the use of formal nonlinear dynamics. Their DSA is ‘a powerful conceptual metaphor’ rather than a developed theory, yet the bulk of the book demonstrates that DSA contributes to the understanding of developmental processes, makes sense out of previously unexplained data, and generates specific predictions which have been verified. Not many schemes that are presented as theories in the behavioral sciences can claim more than that.

It is difficult in the dimensions of a review to give a good idea of the way the authors make flexible and powerful use of these seemingly simple conceptual elements, partly because they give much more than lip-service to the multidisciplinary nature of the issues they tackle. Walking, for example, is a complex but supple coordination of muscles acting on limbs (biomechanical subsystems with many of the properties of springs), of bodily balance, respiration, and general activation, and of emotional states, all taking place in a perceived environment with significant physical aspects (gravity, buoyancy), interpersonal and cultural ones, etc. Painstakingly detailed studies of the kicking of a baby lying on its back show the spring-like nature of the neuromuscular system, so that the ‘regular timing of flexions and extensions . . . can “fall out” without being explicitly planned’ (p. 81). The pattern is so stable that it looks ‘hard-
might have done.

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tional milestone, yielding a deeper ways in which they achieved the same devel-
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important aspect of data: ‘an index of the 
strength of the behavioral attractor, and ... an 
important concomitant of transitions to new forms’ (p. 87). Indeed, they argue, it is this very 
instability of behavior that makes development and creativity possible. And they make the very 
important point that the unexamined traditional assumption rather directly steers our research 
design and choice of statistics, preventing us from noticing that behavioral variability is not 
merely a nuisance or even a sign of bad controls but a basically significant aspect of behavior.

A related implication of the new framework is that ‘the individual and his or her behavioral changes 
over time are the fundamental unit of study’, not group averages (though the data from studies of 
individuals may of course be pooled). A good example of what they mean is afforded by 
accounts of how two infants solved the same problem: reaching for an attractive toy. A vigorous, 
active, bouncy boy’s starting state was an exuberant flailing of his arms. For him, therefore, 
the problem was to calm this spontaneous activity down enough to make more than fleeting 
contact with the toy. A quiet, contemplative girl preferred sitting with her hands on her chest 
or in her mouth; the main task for her was to mobilize enough counter-gravity force to get her 
arm up and out. Phase-plane plots of their movements dramatically illustrate the different 
ways in which they achieved the same developmental milestone, yielding a deeper understanding of the actual developmental process than any quantity of group-averaged data might have done.

It is far from enough, Thelen and Smith argue, merely to say that heredity and environment interact in development. That is by now a truism; the problem is, in detail, how? The DSA gives a useful framework within which to work out those details, one that makes sense of such research as that of Georgopoulos and colleagues on cortical processes preceding and accompanying reaching in the monkey, and that of Freeman and his coworkers on EEG patterns in the cortex of rabbits as they sniff various odors, as well as divers studies in developmental psychology.

To do that, the emerging conceptual framework must have a base in neuroscience. The authors therefore turned to Gerald Edelman (e.g., 1987), whose theory, though ‘speculative in some respects, ... is also ... the first attempt to integrate contemporary neuroanatomy, neuro-embryology, and developmental psychology in a cohesive and plausible fashion’ (p. 130). [Unable to make an informed independent judgment, I can only record my assent.] With an interesting echo of earlier GST work on homologies between theories of evolution and of learning (e.g., Pringle, 1951), Edelman highlights the many sources of variability in the structure and functioning of neurons, and their extensive interconnectedness. Large arrays of neurons become selected by experience, by being simultaneously activated and thus formed into groups. Thus, perceptual categories or generalizations emerge in the overlap of such groups formed by the perception of many single objects. Some kind of increase in synaptic efficiency, assumed to occur as a result of practice, is invoked to explain the coherence of neural groups.

An important aspect of the theory of neuronal group selection is that processes need only occur together in time for the corresponding groups to become interconnected. This process, called reentry when both perceptual and motor neurons become cross-linked, also accounts for ‘coordination of responses across several sensory modalities’ (p. 149). Thus, ‘the global functions of categorization—memory, learning, and performance—arise dynamically from the reentrant mapping of motor activity along with sensory information from many modalities’ (p. 160). In this scheme, the structural basis of memory, including stored concepts and abstractions, is again in the hypothesized synaptic changes that subserve neural group formation. No separate memory storage is assumed.

Indeed, the authors specifically reject the hypothesis that stable, abstract symbols may be the ‘redescription’ of neural groups or their transcription and separate storage. That would involve homunculi of some inadmissible sort, they believe. They do not mention the facts that argue for separate recording of short-term and
long-term memories. ‘This is a radical reinterpretation of concepts’, the authors concede (p. 182). If continuing experience with the study of thinking in adults had confronted them with the necessity of explaining the varying grades of memory and the extraordinary flexibility and efficiency of abstract thought, their exposition might have been more convincing—or might have been different. As it stands, however, the presentation makes no provision for what ego psychologists called the autonomy of (adult) thought, its ability sometimes to reach correct conclusions despite the presence of emotions, strong motives, even severe mental illness.

The model does fit the authors’ data well, however; for example, the sorts of phenomena Piaget called sensorimotor intelligence or the synesthetic unity of the senses in babies. In roughly the second half of the book, as they apply it to the reinterpretation of data gathered by others on a diversity of developmental tasks, the results are somewhat mixed. Often they brilliantly clear up findings that previously were inexplicable in terms of standard theories, but sometimes the effort is strained and not convincing.

The book would have been more convincing if the authors had frankly admitted that they do not have satisfactory solutions for many problems, or even promising leads. They were brave to face the thorny task of conceptualizing motivation, but were led astray by the superficial similarity of Kurt Lewin’s ‘dynamic theory’ to DSA. Despite his talk about force fields, vectors, and valences, and his use of the nonquantitative geometry of topology to represent the ‘psychological dynamics’ of lifespaces, all of that proved to be no more than a metaphorical language in which to talk about ingenious experiments. Thelen and Smith missed a good opportunity to distinguish the kind of dynamics toward which they are striving from Lewinian and psychodynamics in which the only way to measure the postulated forces is by the very behavior they are supposed to explain.

The dynamic systems approach has a long way to go, therefore, before it can be considered a scientific theory. At present, the forces postulated can only occasionally be directly measured. Fortunately, the present explosion of work in the neurosciences holds out hope for new methods for quantitative studies of real forces in real nervous systems. Perhaps the major task of psychology in the next century is to synthesize the rapidly accumulating body of data from this burgeoning field with behavioral and phenomenal observations. Despite its minor flaws, Thelen and Smith’s book seems to me the most promising current attempt to cope with this enormous challenge.

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REFERENCES


This book introduces a conceptual framework (named NIMSAD) and describes how it can be used to evaluate critically three well-known information systems methodologies, SASS (Structured Analysis and System Specification), ETHICS and SSM (Soft Systems Methodology). The author (also the originator) is currently the Professor of Information Systems at the University of Central Lancashire and holds the chair of the BCS Information Systems Methodology Specialist Group; he is also a past chair of the UK Systems Society.

The book consists of four parts. Part 1 reviews the context of methodologies with an excellent

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1 NIMSAD: Normative Information Model-based Systems Analysis and Design.
2 ETHICS: Effective Technical and Human Implementation of Computer-based Systems—can be and is used for design in general and is not restricted to computer-based systems.