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Dynamic Systems Theory

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Diversity is the hallmark of human behavior: Regardless of age or experience, people's performance changes dramatically depending on context, including the presence of different people. The same sixth-grade student who can easily solve a difficult math problem in class often cannot solve the same problem at home on her own, or even in class the next day. These kinds of fluctuations in performance can be frustrating, but they are normal. The fact is that variation is a part of all human behavior. Yet despite its pervasiveness, variability has frequently been ignored in developmental science. As a consequence, the field now brims with elaborate descriptions about global changes in behavior, but it struggles to explain why a child can recite the alphabet for his parents, but not his teacher.

In recent years, a number of researchers have emphasized the importance of variability, and have sought to explain both stability and diversity in behavior over time. In order to capture the richness and complexity of development, many researchers have adopted concepts, methods, and tools from *Dynamic Systems Theory*—a flexible framework for analyzing how many factors act together in natural systems in disciplines as diverse as physics, biology, and education. Over two decades ago, researchers such as Esther Thelen, Paul van Geert, and Kurt Fischer (and others) helped pioneer the application of dynamic systems to development. Their work laid the foundation for a fresh approach to understanding how people learn, grow, and change.

Formally, dynamic systems theory is an abstract framework, based on concepts from thermodynamics and nonlinear mathematics. However, whereas some of the concepts (and much of the terminology) may seem foreign to researchers and practitioners, the *principles* of dynamic systems theory are very straightforward, and deeply relevant to the study of human behavior. The dynamic systems approach in development starts with two principles: (1) Multiple characteristics of person and context collaborate to produce all aspects of behavior; and (2) variability in performance provides important information for understanding behavior and development. Taken together, these principles—person-in-context and variability-as-information—represent the backbone of dynamic systems theory. Building on these themes, researchers have overturned misconceptions and resolved long-standing arguments about the nature of development.

Person and context together

In the game of baseball, the pitcher's job is to throw the ball for a strike. However, even the best pitchers cannot do this every time. Why not? The simple answer is that throwing a ball accurately—like all human behavior—always depends on more than just biology and experience. Context matters! In fact, so many contextual factors influence the accuracy of any given pitch—temperature, crowd noise, or having a runner on base (to name but a few)—the performance of a pitcher cannot be understood outside the immediate context. This is true for all behaviors, not just tossing a baseball. Behavior is not something a person 'has': it *emerges* through the interactions between person and context, and depends on many biological and contextual factors. Traditional models assume that people have stable skills, and discount the importance of person-in-context – the dynamics of behavior. However, ignoring these dynamics can lead to serious misconceptions. The case of the infant stepping reflex illustrates this principle nicely.

Newborns have many primitive reflexes, including the 'stepping reflex': the pattern of leg movements (steps) an infant makes when held upright. Present at birth, this reflex disappears after a couple of months, only to reappear around the time of walking—something that puzzled researchers for decades. Classic explanations for this phenomenon were based on the neurology of infants: Brain areas matured and then suppressed the newborn reflex. This was the established view until Thelen, using dynamic systems theory, offered a different explanation, considering characteristics of infants' bodies that the brain explanation treated as irrelevant. The stepping reflex disappeared not because of neurological changes but because of changes in leg weight: Babies' legs showed an increase in mass (subcutaneous fat as well as other tissue) that made it impossible for an infant to lift his or her legs from an upright position. Showing the importance of context, Thelen tested infants who had seemingly lost the reflex by placing them into a tub of water, where the buoyancy reduced the effective weight of the legs. Now, when the infants were held upright, their reflex returned and they stepped just like younger infants! By manipulating non-obvious variables, Thelen was able to control the emergence and suppression of a reflex once thought to be under strict neurological control. In this case, the key principle of person-in-context helped researchers discover the underlying dynamics of infant motor development.

Variability as information

People routinely show this kind of variability in behavior, rarely performing at a single fixed level consistently. All behavior emerges through interactions between person and context, and thus performance varies dramatically and systematically depending on many factors such as arousal level, emotional state, task demands, and assessment conditions (to name a few). In contrast with classic models, dynamic systems theory treats variability as information, and seeks patterns and order in the variation. Because variability is analyzed instead of ignored, researchers are able to identify factors that have a systematic effect on behavior and development – to find the order in the variation. Fischer has shown that one powerful source of variability is contextual support: With priming of key ideas or actions through the help of an adult or a well-designed computer program or text, a person can perform at a higher level, but they cannot sustain the performance without such support.

Madison, 16, demonstrates the influence of contextual support through her understanding of the relation between addition and multiplication—both of which involve combining numbers to get larger numbers, with addition combining single numbers and multiplication groups of numbers. This relation is difficult for adolescents to articulate, but around 15 or 16 years, they can understand the concept if they have contextual support. In Madison's case, she has no problem getting the relation when her teacher prompts the key ideas, and she can even provide specific examples (5+5+5+5 = 20 and 5 x 4 = 20). However, when discussing it with her parents or friends, her performance drops dramatically—for example, she says that addition and multiplication are the same but cannot explain the essential difference (single numbers versus groups) that she understood with her teacher's support.

Madison's performance speaks against the notion that people have a single level of ability: What would her 'true' level be? In reality, Madison clearly varies between two levels of performance, what Fischer calls the developmental range: She understands the relation with support, but she does not understand it without support. The skill is both present and absent, depending on the context. In other words, it is dynamic!

The importance of support is hardly controversial. However, when studied through the lens of dynamic systems, contextual support can reveal surprising facts about learning, and it offers a simple solution to the classic debate about stages. Using nonlinear models from dynamic systems, Fischer studied patterns of development in conditions of high- and low-support independently. When growth was assessed under high-support, it showed clear stage-like properties. However, in low-support conditions growth was smooth and continuous. Through the careful use of dynamic systems tools, and by treating variability as information, Fischer was able to show that stages both do and do not exist, depending on the dynamics of the activity!

Conclusion

Human behavior is flexible and dynamic. Whether tossing a baseball or solving a math problem, behavior comes from more than just the person, and more than just the context: It is always about the person-in-context. Many different factors (biological and contextual) influence performance, and this makes behavior both complex and variable. Any meaningful account of development must be able to explain behavior in all its richness and variation. Dynamic systems theory offers powerful concepts and tools both to capture the stability of behavior over time and to explain why a young child reads better for his parents than his teacher. Explaining stability and change *together* is a key strength of dynamic systems theory.

Suggested Readings:

Fischer, K. W. & Rose, L. T. (2001). Webs of skill: How students learn. *Educational Leadership*, *59*(3), 6-12.

Fischer, K. W. & Bidell, T. R. (2006). Dynamic development of action and thought. In W. Damon & R. M. Lerner (Eds.), *Theoretical models of human development. Handbook of child psychology* (6th ed., Vol. 1, pp. 313-399). New York: Wiley.

Thelen, E. & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.

Van Geert, P. & Steenbeek, H. (2005). Explaining after by before: Basic aspects of a dynamic systems approach to the study of development. *Developmental Review*, *25*, 408-442.