Journal of Abnormal Child Psychology, Vol. 32, No. 6, December 2004, pp. 665–671 (© 2004)

Trouble Ahead: Predicting Antisocial Trajectories with Dynamic Systems Concepts and Methods

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Received July 7, 2004; accepted July 16, 2004

This paper reviews and evaluates a set of studies that utilize dynamic systems (DS) principles, and in two cases dynamic systems methods, for predicting antisocial development and other behavioral outcomes. I suggest that the emphasis of DS approaches on process and nonlinear causation is very different from the emphasis in developmental psychopathology on prediction, yet the marriage of these approaches is necessary to capture the complex interactions that give rise to problematic trajectories. The studies reviewed do indeed uncover predictive relations that would have been difficult to conceptualize or impossible to find using more traditional strategies. In discussing these studies, I suggest DS interpretations of emerging individual differences, phase-specific change, sleeper effects, mediating variables, and behavioral rigidity versus malleability, in the context of developmental prediction. I also discuss the advantages of moving from DS concepts to DS methods in clinical-developmental research.

KEY WORDS: dynamic systems; socialization; developmental prediction; antisocial behavior.

Dynamic systems (DS) approaches in developmental psychology have grown and diversified over the past decade and a half. Thelen's study of motor development and Fogel's analysis of infant–mother behavior patterns first attracted attention in the late 80s and early 90s (e.g., Fogel & Thelen, 1987). Throughout the 90s, researchers in cognitive and language development used the DS lens to examine real-time performance and profiles of developmental change (e.g., Smith, 1995; van der Maas & Molenaar, 1992; van Geert, 1991). More gradually during the 90s, DS approaches to emotional development began to focus on the patterning of facial expressions, emotional behaviors, and emotion regulation (Camras, 1992; Fogel et al., 1992; Lewis, Lamey, & Douglas, 1999). Finally, in the last few years, the study of social development has adopted DS methods sensitive to the fine-grained structure of children's interpersonal interactions (Granic & Hollenstein, 2003; Granic, Hollenstein, Dishion, & Patterson, 2003; Hsu & Fogel, 2003; van Geert & van Dijk, 2002). DS approaches have appeared in other areas of psychology as well, including the study of groups (Arrow, McGrath, & Berdahl, 2000), marital relations (Gottman, Murray, Swanson, Tyson, & Swanson, 2002), and clinical processes (Tschacher & Scheier, 1997). Yet the field of developmental psychopathology, lying at the interface of developmental and clinical investigation, has made little progress in DS-inspired research. Despite long-held assumptions about the systemic nature of individual trajectories, interest in the biological substrates of problem behaviors, and attraction to notions of self-organization and complexity (see Lewis & Granic, 1999), developmental psychopathologists have generally not informed their research practices with DS concepts or methods.

Given this lag, it is exciting to see several articles in this special issue that explicitly draw on DS ideas for conceptualizing and researching developmental processes that lead to problem trajectories. As is typical of research in developmental psychopathology, these studies examine relations between early problem indicators (risk factors), mediating variables, and outcome variables, and/or they assess changes in outcomes measured across several longitudinal waves. In other words, they integrate DS ideas into research focused on prediction. Indeed, much

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of the practical value of research in developmental psychopathology is in its predictions. How do we know before things go wrong that they will go wrong, or are likely to go wrong, or are likely to go wrong given the presence or absence of certain conditions? Such knowledge is crucial to guide administrators, clinicians, and educators toward preventive practices for children and their families. But is prediction compatible with DS approaches to development? Many researchers understand prediction in terms of linear relations between precursors and outcomes, where increments in one variable are proportional to increments in the other. DS approaches generally highlight nonlinear (complex, indirect, disproportionate) relations among causally connected events, multiple causality, feedback relations, and so forth. Moreover, DS approaches construe time as continuous, and there is little interest in identifying "before" and "after" variables. In fact, the chief contribution of the DS paradigm seems to be in the understanding of process, not outcome. Given these incompatibilities, a marriage between DS principles and the pragmatics of prediction could be rocky.

Several questions come to mind in anticipating such a union. First, predictive relations between precursors and problem outcomes are usually surprisingly weak. Although we get accustomed to correlation coefficients in the 0.2–0.4 range, we should continue to ask where all the rest of the variance (up to 96%) went, and how much cause and effect is captured by these associations. Are the linear assumptions in traditional designs responsible for low coefficients? If life really is complex, multidetermined, and characterized by recursive interactions, then maybe a DS approach to prediction would help capture more of the connection between precursor and outcome events. Both the nature of developmental causation and the shape of developmental trajectories could be revisited from this perspective. Second, in recognizing the complexity of developmental processes, and the indeterminacy of precursors at any age, conventional approaches often look at mediators that contribute to predictions from risk factors to outcomes. However, mediators are usually expressed as values for each individual on one or a few variables (counts, frequencies, scale values, etc.). To what degree can these variables capture complex processes in the real world, including reciprocal interactions among social partners, emotions and behaviors, and expectations and consequences, as they play out over repeated occasions? DS approaches assume a multiplicity of causal factors that interact within developmental periods, as well as the second-order complexity of causal factors interacting across developmental periods. It is worth exploring whether this view of complexity helps provide a more precise and powerful representation of mediating effects. Third and last, critics of DS approaches sometimes ask "what good are they?" To put it bluntly, how much do we care about the fine-grained structure of behavior and the multifaceted web of developmental pathways unless we can make predictions, especially predictions that are falsifiable? Furthermore, DS approaches have remained largely at the level of basic research, so if these predictions can be applied to help people in the real-world, all the better. Thus, it might be advantageous to yoke DS models, designed for understanding how complex systems work, to research designs focused on prediction, particularly predictions that have relevance for children's mental health.

These questions and concerns will now be addressed directly by examining the innovations, strengths, and weaknesses of the DS-related articles in the special issue, and other issues will be addressed as they come up. Some of these studies are anchored in conventional research strategies, but they use DS principles to help think about developmental processes, elaborate conventional designs, and interpret their results. Others take the additional step of introducing DS principles into the design and methodology of the research as well as the conceptualization of the processes being studied. These papers can help to launch the marriage of DS and prediction in developmental psychopathology. The couple looks quite compatible from some vantage points, less so from others, but hopefully heading for a solid marriage despite their differences.

Snyder, Prichard, Schrepferman, and Patrick (2004) view the path from early attentional issues (impulsivity and inattention) to later conduct problems according to several principles that are basic to DS developmental approaches. Like other researchers in social development, they see the path from risk to negative outcomes as influenced by important mediating variables. But they go the extra step of thinking about mediators in terms of reciprocal and recursive processes that play out over time during sensitive periods. First, they assume that early attentional problems are *amplified* through negative social interactions and then *stabilize* as persistent conduct problems. Viewing the emergence of individual differences in this way is basic to the idea that developmental trajectories self-organize (Keating, 1990; Lewis, 1995). Second, these growth and stabilization processes are argued to take place through iterative causal processes, and the authors go on to speculate about the structure of an underlying feedback cycle. They suggest that children with poor attentional skills use pushy and aggressive strategies, their peers respond with rejection or counter-coercion, the problem children become more isolated and entrenched in their ineffective strategies, and so forth. Finally, these authors see the transition to elementary school as a pivotal period,

what DS theorists call a *bifurcation point* or *phase transition* (Thelen & Smith, 1994). These are periods of development when systems undergo qualitative reorganizations, reflected in a temporary increase in the variability of behavior. The phase transition construct is useful because it helps explain how tendencies inherent in children's dispositions become realized through mediating interactions with the environment only at particular ages. Thus, Snyder et al. (2004) essentially view mediator processes in dynamic terms, a perspective that appears to help ground their hypotheses about the effects of peer interactions on later problem outcomes.

The methods used to assess these processes are more conventional. The contribution of precursor and mediating variables to a linear growth model (level and change in ratings of problem behavior) is assessed through structural equation modeling, and mediating effects are partially confirmed through this analysis. The authors rightly conclude that both additive and mediating effects represent complex causal processes in the social ecosystem of these children, augmenting and refining conduct problems at the beginning of the school years. That these effects were more critical for growth than for initial levels of conduct problems suggests a sleeper effect or, as discussed next, a buildup of influence through recursive processes. However, as noted briefly as a limitation of the study, it would be useful to look at *change* in peer processes in relation to *change* in conduct problems. Only through such a dynamic assessment could the actual causal mechanisms leading to isolation and aggression, and the feedback relations in which they are embedded, be precisely identified. Evaluating peer interaction factors as independent predictors begs the question of change in peer processes, even though the authors have good intuitions that such change fuels long-term outcomes. Perhaps this methodological limitation reflects a conceptual agnosticism about what a mediator really is—an unfolding process or a single phenomenon. If the marriage of DS and prediction approaches is ever legitimized, this ambivalence will have to be ironed out.

Several DS principles are also adopted by Patterson, DeGarmo, and Forgatch (2004) in their study of the clinical impact of Parent Management Training. This randomized treatment study involved mothers and children who have recently come through a divorce, assessed across five longitudinal waves beginning just before treatment initiation. The authors were principally concerned with "collateral changes" in the relations among maternal depression, parenting practices, and boys' antisocial behavior patterns. Collateral changes are changes in the elements of a system that co-occur over time, or coevolve. The assumption here is central to DS approaches: change is a result of reciprocal interactions playing out over time. Like Snyder et al. (2004), these authors assume that mediator effects represent such iterative processes. A second DS principle has to do with developmental causation. If mediating variables represent iterative causal processes, then their effects on developing systems must be recursive (growing in a cyclical, self-enhancing fashion). Recursion implies a kind of causation that buildsup over time. According to DS approaches, this may be the only kind worth considering. Something that happens once or twice tends not to affect system organization. Only something that feeds back on itself, or feeds forward to later renditions of itself, has a chance to influence the developmental reorganization of individual and dyadic systems. The authors ask whether treatment-related change exemplifies this kind of effect, thereby qualifying as a process of self-organization.

Thus, Patterson et al. (2004) conceptualize the relation between treatment, parent change, and child behavior change in terms of reciprocal causation, feed-forward, and self-organization. These DS constructs inform two steps of their data analytic strategy, if not their methods per se. In the first, bidirectional influences between maternal depression and maternal parenting practices (within the same time slice) are tested, and a weak relation is found only from effective parenting to reduced depression. In the second, a nonlinear relation between change in maternal depression and parenting practices is explored. The results indicate that reduction in maternal depression in the first 12 months of the study contributed independently to effective parenting at 30 months (over and above same-time effects). The authors rightly interpret this effect as a feedforward process, one component of a self-organizing developmental process. It is also reminiscent of Snyder et al.'s (2004) finding of a sleeper effect on the growth of antisocial behavior over Kindergarten and Grade 1. However, their very conservative test, partialling out the influence of effective parenting at baseline and following treatment, cuts away much of the potential signal as though it were noise. If reciprocal relations between depression and effective parenting exist, parenting effectiveness ought to feed back on itself both within and across time periods. A full feedback/feedforward model should include both within-wave and cross-wave effects.

As with Snyder et al. (2004), these authors use nondynamic (traditional) SEM methods to get at processes they conceptualize as iterative, complex, and emergent. Thus, it would not be surprising if their findings underestimate the power of the causal processes they wish to consider. Patterson et al. (2004) recognize this limitation, but they claim that fine-grained measures of the various contributing factors are not available in most clinical studies. Indeed, these authors collapse real-time process measures

into construct scores, frequencies, conditional probabilities, and scale scores on various assessment instruments. Even their so-called "microsocial" measures are static variables that can be inserted into structural models. Yet a variety of microdevelopmental or microgenetic methods are available for developmental research (Granott & Parziale, 2002). Moreover, Granic and Hollenstein (2003, in press) argue that the chief impediment to a DS approach to developmental psychopathology is the tendency of investigators to collapse time-based measures into static (time-free) measures. What goes on between a mother's depressive mood, a parenting intervention and a child's reciprocation is not invisible, but unique methodological tools are necessary to capture it. Of course, prediction does require collapsing of some sort, and thousands of moments of emotional and behavioral events need to be represented by some generalization in order to predict the (generalized) future. Conditional probabilities are probably the most sensitive way to do this using method already familiar to developmentalists. However, new techniques such as state space grid analysis (Hollenstein, Granic, Stoolmiller, & Snyder, 2004) and Dishion, Nelson, Winter, and Bullock's (2004) entropy analysis look at the organization of behavior at the level of the system rather than the level of simple events. These will be important commodities if this marriage is to succeed.

The papers reviewed so far deal with mediating variables in self-organizing developmental processes—in one case the impact of peer interactions, in the other the relation between parental mood and behavior. Although both these papers discuss the complexity of mediating processes in the amplification of behavioral tendencies, their methodologies do little to get at this complexity directly. In fact, both articles recognize that the malleability versus rigidity of social processes are critical to the prediction of developmental outcomes. Snyder et al. (2004) study children at the transition to school age because children's social habits become reorganized through peer processes at this time. Patterson et al. (2004) recognize the importance of an early therapeutic perturbation to maternal depression, shifting the dynamics of a system that would otherwise become increasingly entrenched. Thus, both papers recognize that the structure or organization of the system—its degree of rigidity versus flexibility—is a critical parameter for social developmental change. It would not be difficult to measure this parameter directly.

Dishion et al. (2004) take the next step by deriving new, DS-inspired methods for studying antisocial development. They examine the peer interactions of antisocial children in comparison with normal children, with an eye not only to the content of children's discourse with their peers but also to the degree of structure (vs. malleability) in the child–peer system. From previous research they determined that higher levels of "deviant talk" (talk about breaking rules, taking drugs, etc.) independently predict antisocial outcomes, and that children already on a trajectory of antisocial development engage in higher levels of deviant talk than their normal age-mates. However, they recognize that their assumptions and methods to date rely on a learning paradigm, using the quantitative framework of contingency analysis. For them, a DS approach goes beyond contingencies to look at the overall temporal organization of the dyadic exchange. To accomplish this they use a number of observational codes to map out a *state space grid* (Lewis et al., 1999)—a matrix of cells representing all the possible behavioral states available to the dyad. They then analyze the probabilities for moving to any cell from any other cell in the grid, using a formula for *entropy,* the overall level of organization in the state space. High-entropy dyads are disorganized or malleable, whereas low-entropy dyads are structured and predictable. With this measure, they provide information about individual differences in the temporal organization of each peer dyad as a complement to their assessment of the amount of deviant talk.

Some of their hypotheses tie DS notions of behavioral organization to well-researched assumptions about the development of antisocial behavior. For example, the simple hypothesis that antisocial children form more disorganized friendship interactions can only be tested by DS-inspired methods, of which the entropy analysis is a good exemplar. Indeed, this prediction is confirmed. Other hypotheses are more novel and exploratory: in particular, the hypothesis of an interaction effect between entropy (orderliness) and deviant talk in predicting negative outcomes. The authors ask whether highly structured dyads organized around—or "stuck in"—deviant talk might be the mostly likely to evolve into antisocial adults, and they select DS methods over sequential analysis to test this prediction.

The results of this analysis are clear: 14-year-old boys showed the predicted interaction effect. For those with low-entropy interactions (those who were more stuck), the degree of deviant talk functioned as a predictor of antisocial outcomes at age 24. However, for those with high-entropy (disorganized) interactions, the degree of deviant talk was not predictive. The authors rightly interpret these results in terms of the "stuckness" of children in interaction processes that maintain and enhance antisocial trajectories. They then go on to explain the highly structured interactions of some children in terms of "catch up" with their peers. Instead of floundering in states of disorganized peer interactions, some at-risk children become organized and even entrenched in interactions focused on

rule-breaking themes. However, there is a more universal principle by which structure begets prediction. When a system is still malleable, changeable, and open to diverse influences, the present content of that system makes for poor predictions of future outcomes. Anything could happen; the die is not yet cast. Once systems begin to settle down, solidify, and become formed, they are intrinsically better predictors of future outcomes. The future has already begun to consolidate in the present. The authors do suggest that attractors, which are not predicated on reinforcement theory, can be construed as the laying down of long-term habits in children's trajectories (see Thelen & Ulrich, 1991). But one might go further still in classifying the value of orderliness in children's social interactions. Orderliness is a double-edged sword. The fact that antisocial children have more disorganized interactions in general is a liability: they are less predictable, less solid, and perhaps less gratifying to themselves and their peers. Their habits, or nonhabits one might say, are emblematic of younger children. However, Dishion et al.'s (2004) results suggest that disorganized, malleable interaction patterns serve as a protective factor if antisocial children are tempted into the world of deviance. As long as these children remain relatively "unstuck" in their conversational habits, they have the hope of diverging from a potential antisocial trajectory and reorganizing to find another, less harmful form of membership in the social world.

The meaning of orderliness in interpersonal interactions is further investigated by Hollenstein et al. (2004). Using the same sample as Snyder et al. (2004), they attempt to predict teacher-rated antisocial behavior across four waves (kindergarten to grade 1) on the basis of interactions between these children (when starting kindergarten) and their mothers. Their treatment begins with a DS approach to development both in word and in deed, emphasizing the organization of behavior without regard to the content of that behavior. This approach is a major departure because it ignores content entirely. Can orderliness itself be construed as a developmental predictor? Dishion et al.'s (2004) results portray orderliness as a double-edged sword: "good" order allows for more normal friendships, whereas "bad" order entrenches the impact of negative content on future outcomes. Along similar lines, Hollenstein et al. (2004) construe "bad" order as rigidity, and they refer to a longstanding literature linking rigid dyadic interactions to negative personality patterns and psychopathology. Rigidity is viewed as the converse of malleability, adaptability, or the capacity to react sensitively to changing social demands. Rigidity does not need to magnify negative predictions; it should predict negatively on its own. In fact, the authors stipulate that even positive content organized in a rigid pattern should not be advantageous, because families need to down-regulate high arousal and adjust to shifting task demands. Thus, simply by predicting more of itself, rigidity in early parent–child interactions is viewed as a harbinger of diminished flexibility and constricted emotional and behavioral capacities in the child's interactions with other people.

One of the most interesting features of this paper is that characteristics of rigidity are operationalized and translated into simple but novel indices of real-time behavior. These indices get at the process of real-time behavioral organization directly. Hollenstein et al. (2004) use a state space grid, as described earlier, to map out the flow of behavior in real time; but rather than measure entropy as an index of orderliness, they introduce three related parameters. First, rigidity is construed as a diminished behavioral repertoire, so these authors assess the number of cells on the grid occupied by the dyad's behavior: the more cells occupied, the greater the range of behavioral variation, and the less rigidity. Second, rigidity is viewed as a tendency to avoid change, and this gives rise to a measure of the number of transitions from cell to cell: the smaller the number of transitions, the greater the dyad's rigidity (this measure is a simplified equivalent of Dishion's entropy measure). Third, rigidity is viewed as a tendency toward perseveration, and this translates to a measure of the average duration in each cell: the longer the mean duration, the more stuck the behavior. Unfortunately, these measures are combined into a construct score for rigidity, so it is not clear what each contributes on its own.

Hollenstein et al. (2004) find that rigidity in parent–child interactions predicts both internalizing and externalizing behavior patterns, independent of the content of those interactions. But the way in which they measured these relations is critical. Simple correlations estimate the linear relation between predictor and outcome variables. In this study, correlation coefficients, though significant, were uniformly low. Indeed, these coefficients were at the level often found in conventional, non-DS predictive analyses. Thus, there may be little added value in measuring rigidity, or any other DS-informed construct, when relying on linear predictions. Low coefficients may simply be a function of linear methods rather than how precursors are conceptualized. However, predictions to the upper 10% of externalizing and internalizing scores showed a more interesting pattern. Across the four outcome waves, the high externalizing group was increasingly predicted by early rigidity. Similarly, it was those children whose externalizing behaviors increased or remained high over the four waves who were most likely to have had rigid interactions. These effects appear to be nonlinear, and they are

more consistent, more interesting, and account for more variance than the bivariate correlations. But what do they mean?

These results seem to suggest a sleeper effect in antisocial development, as implied by some of the findings of Snyder et al. (2004) and Patterson et al. (2004). Rigidity in parent–child interactions has greater impact on problem behavior over time. A linear view of development would imply that proximal cause–effect relations are more powerful than cause–effect relations over greater time lags. However, viewing developmental causation in terms of a build-up of influence, perhaps underpinned by accelerating cycles of rigidity in parent–child interactions, leads to different expectations. Recursive causes "launch" outcomes that continue to grow over time. The best measure of a causal influence of this type should come later rather than earlier in a developmental sequence. Hollenstein et al. (2004) are right to emphasize that rigidity predicts the growth of externalizing behavior, given trajectories that start at about the same level. But they don't seem to know what to make of these findings. Much of the power of their approach may be in the prediction of growth *instead of* static outcomes, because this effect captures the nonlinear nature of developmental causation. It may also be more important for prevention science to predict growth than level of problem behaviors. Thus, these authors' approach to prediction suggests a unique role for DS-inspired methods. However, it seems that their measurement of rigidity could be developed further. Transition rates and mean duration values are very simple measures, perhaps too simple, and their application to all grid cells, without regard to content, opens the door for conflation between rigidity ("bad order") and stability ("good order"). One does not need to ignore behavioral content in order to get at the structure of developing systems, as demonstrated by Dishion et al. (2004). A long-duration positive exchange simply cannot mean the same thing as a long-duration negative exchange, and the exploration of rigidity through DS-inspired methods will do well to capitalize on such differences.

These four papers provide us with a useful springboard to future applications of DS/prediction approaches. They also suggest avenues by which the other research programs represented in this special issue could incorporate DS strategies. Deater-Deckard, Atzaba-Poria, and Pike (2004) recognize that parent–child mutuality is a bidirectional social process, and this insight points toward a possible DS analysis. In their work so far, these authors have measured parent–child mutuality with a single variable incorporating global ratings of responsiveness, in order to predict externalizing behaviors. The predictive relations they find are significant, but the strength of these relations might have been enhanced had mutuality been measured dynamically. Global ratings miss the fine grain of interpersonal behavior. One might videotape this behavior, mark moments of mutual affection or other synchronous states, and then derive values for the duration of these moments, the tendency to return to them, their relative strength or weakness after disengagement, and their latency to resume following angry words. These parameters would show how flexible the system is in reintroducing mutual affection following a dispute, and this sort of repair might portray a recursive causal process critical for shaping trajectories. Stormshak, Comeau, and Shepard (2004) predict drug use from sibling and peer deviance. Again, rich videotaped discussions about drugs between the target child and sibling were collapsed into global constructs used to predict outcomes. Had the organizational structure of these interactions been preserved, using Dishion's entropy measure or other state space grid variables, then one could discover whether the impact of sibling deviance on negative outcomes was mediated by the orderliness, consistency, or variability of the sibling exchange. Also, bidirectional effects between peer and sibling contributions to child outcomes are mentioned but they are not measured. Analyzing several discussions over time could show the growth of drug-related talk among siblings, providing clues as to how this process becomes amplified recursively with peers. Such an approach would provide more detailed information about the causal forces at work both at home and at school.

In conclusion, the four papers that utilized DS constructs point in several ways to the value of a marriage between DS and prediction approaches in developmental psychopathology. Three of the four studies provide some evidence for nonlinear as well as, or instead of, linear developmental profiles. Predictions of growth over and above the level of antisocial behavior, and predictions to subsequent change controlling for recent change, both point to the nonlinear and emergent nature of antisocial trajectories. Moreover, sleeper effects reflect a certain kind of causation, based on the build-up of influence through recursive processes. Three of the four studies also tackled mediator effects. Although such effects were accessible to both traditional and DS-based methods, the latter approach captured the structure as well as the content of interactions contributing to predicted outcomes. Finally, the prediction of antisocial outcomes put DS methods to the test in two studies. Predictions in science come in many flavors, but in developmental science, where causal manipulations are often impossible, one of the best ways to validate a model is by predicting the future of naturalistic processes. Thus, it is encouraging that developmental predictions in two studies showed hypothesized effects

of the structure of interpersonal interactions on antisocial outcomes. Finally, the marriage of DS and prediction has unique implications for treatment and prevention. Patterson et al. (2004) began their article by wondering why parenting practices continue to improve, or maintain improvement, rather than returning to baseline, at the termination of treatment. The study of self-organizing systems finds that evolving systems *never* return to baseline. Rather, change is self-perpetuating. A key question for treatment then is how to build up enough "thrust" to catapult the system through a bifurcation or phase transition—a fundamental structural reorganization—with the knowledge that such change will not get lost.

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