Dynamic Systems Research on Interindividual Communication: The Transformation of Meaning-Making

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Abstract: *This paper presents a dynamic systems methodology for the study of interindividual communication in social systems. Since dynamic social systems are fluid, changing, emergent, developing, and yield created information in a meaning-making process, it follows that dynamic systems research best serves scientific discovery by substantiating these same processes in the method. The dynamic systems methods presented here place the scientist in the system, not knowing the answer, but working through a dynamic process of engagement with the system, toward an emergent understanding of the patterns of communication and their changes over time with respect to the limitations of the observer's method and point of view.*

Introduction

Dynamic systems theory addresses the problem of describing the ways in which complex systems change over time. The focus of this paper is to highlight the unique conceptual and research issues that arise when change in social communication systems is the topic of investigation. Specifically, in addition to quantitative indices of change in frequencies, durations, and sequential patterning of communicative behavior, research on communication can also encompass the meaning in the system. Meaning, similar to any other pattern formation process in a dynamic system, can be thought of as emerging and stabilizing dynamically through a process of self-organization. This paper presents a research model that includes both developmental changes in quantity and in meaning. These terms are defined and the methods are explained and illustrated in a lengthy research example.

The study of change is paradoxical. The phenomenon that one wishes to observe in one moment is no longer the same in the next moment. Yet, as human observers, we are capable of perceiving and describing when behavior at two or more moments in time appears to be the "same" or "different" (Popper, 1968). This is particularly relevant to the problem of studying communication because meaning can be defined as the perception of a “difference” between two or more communicative actions. But the meaning of the perceived difference can only become manifest in the changing actions or interpretations of participants in a communication process. Meaning-making is thus part of the way in which human observers interpret some complex series of changes as “having” a pattern, structure, or order. Any time an observer declares the presence of a pattern, in other words, the observer becomes a part of the dynamic system being observed. The stars in a galaxy do not in fact have, own, or possess a pattern. The pattern (the galaxy) emerges in the relationship of the stars to the observer.

The study of complex dynamic systems takes as a premise that individual components and constituents are best understood as part of a collective in which each affects the others to create pattern and order at the level of the collective, an order which may not be obvious at the level of the behavior of each of the constituents. *This paper takes the perspective that the study of dynamic systems involves one additional constituent to any collective that is being observed: the observer’s point of view*. The observer, in other words, is part of the description or model of the system. Although complex systems exist in the absence of the observer, the patterns and processes that are described, counted, and analyzed emerge from the relationship between the observer and the system. This point refers to the role of scientists on systems in which they are not participants. Should they be participants, their behavior and presence becoming part of the system, in addition to their point of view contributing to how that system comes to be understood by others?

The pattern, furthermore, emerges over some finite period of time. One looks at the world and patterns seem to appear instantaneously. There is, however, at least some period of microseconds required for the brain and sense organs to organize the perceptual flow into a flower, tree, or galaxy. Even that relatively rapid emergent process, however, is founded upon an earlier, and considerably longer, period of engagement in that person’s life, a period in which patterns were not apparent and needed days, weeks, or months to be discovered through some process of engagement with the world. The pattern coalesces and stabilizes into a consistent attractor in the brain-behavior-sensory system, making the recognition of the pattern on future occasions more rapid and efficient (Lewis, 1995; 2005; Thelen & Smith, 1994).

This longer process of meaning-making could, of course, be applied to an infant or child who must discover through perception and action, or “re-create,” the meanings of words and gestures via a process of co-regulation with adults (Fogel, 1993; King, 2004). In this paper, however, we apply the same notion to the scientist. Faced with a complex system whose patterns do not easily appear to the observer, patterns may—through a process of prolonged engagement, discovery, and meaning-making—finally emerge.

It is not the intention here to review the growing literature on dynamic systems research and theory. Where needed, the principles of dynamic systems theory are briefly mentioned. The central theme of dynamic systems theory is to understand how the patterning of the collective is related to the co-regulation between the constituents. In the view of dynamic systems theory, the constituents of a system act together to constrain the multiple actions of other constituents so that the complex system organizes and reorganizes over time into a series of semi-stable patterns of behavior called *attractors*

(Kelso, 1995; Kugler, Kelso, & Turvey, 1982; Prigogine & Stengers, 1984). Constituents, in other words, change each other in the process of convergence toward an attractor. Two people in a long-term partnership change each other in the process of forming a "couple" with recognizable patterns and habits.

Each time an attractor is re-constituted, the actions within the attractor, the microlevel activity of the system, are somewhat different from the previous occurrence of that same attractor. The concept of dynamic stability replaces the concept of structure, habit, and association in traditional theories of behavior regularities (Capra, 1996; Fogel, 1993; Thelen & Smith, 1994). The attractor occurs at an organizational, collective, or macrolevel of activity, in which the observer's perception of "sameness" becomes possible.

In the behavioral sciences, complex systems occur for intraindividual, interindividual, ecological, and sociocultural relationships. The *intraindividual system* involves relationships between the various systems of the body and mind, such as between genes and their cellular environment, between brain and behavior, between muscles that act together to perform an action, or between emotion and intellect. The *interindividual system* involves social relationships such as between parent-child, close companions, teacher-student, supervisor-employee, therapist-client, romantic partners, and business partners. The *ecological system* includes relationships between humans and their physical and biological environment such as our relationships with the plants, animals, and the earth. The *sociocultural system* contains all the relationships within and between groups of people with intersecting histories; it takes in relations of international peace or conflict, systems of kinship and religion, of politics and economics, institutions of education or medical care, systems of government and law.

The Paradox of Change and the Role of the Observer

Attractor patterns may become salient to observers in each of these systems. Any type of stable behavior pattern in the intraindividual system, such as walking or smiling, involves microlevel co-activity between muscular, skeletal, neurological, endocrine, and immune systems of the body. Greetings, leave-takings, topics of conversation, and the like are seen as stable attractors in the interindividual system. Taking a pet dog for a walk, or creating artificial ladders for migrating salmon to traverse dams and other human structures on their way upstream, are examples of attractors in the ecological system. Treaties, laws, elections, and classrooms are attractors in a sociocultural system. In these examples, attractors are perceived when patterns of linkage between microlevel constituents recur with regularity and with relatively little variability.

In interindividual communication, for example, people can easily perceive and label the attractor called "greeting" at the macrolevel, even though there are many different types of greetings (formal or informal, distant or intimate, face-to-face, or through some electronic medium). These different types of greetings all show differences in the microlevel of activity within the perceived "sameness" of the attractor pattern. Even within the same interindividual relationship over time, every face-to-face greeting is somewhat different in the microlevel pattern of activity. The same pair of romantic partners, for example, sometimes kisses, sometimes hugs, sometimes nods, or does some combination of these and other actions. In sum,

- Dynamic systems are always changing.
- Patterns of stability can be perceived from the flow of change.
- "Change" and "stability" are emergent from the engagement of the observer with the system.
- Science is the pattern of meanings that are made from the observer-world system.

This brief discussion highlights a series of methodological dilemmas that a scientist/observer faces when attempting to understand and study changing dynamic systems.

- Is it possible for scientific meanings to transcend the particularities of how, when, and by whom something is observed?
- Is it possible to capture and analyze a phenomenon that is always changing, that is, is there any such thing as a "phenomenon" to be studied?

These questions may seem to be best left to philosophers rather than to scientists. Shouldn't scientists stick to being concrete and practical? Perhaps a scientist may wish for such simplicity. After all, if people can perceive attractors readily, then it should be a relatively easy task for a scientist to make recordings of all instances of greeting patterns in a particular sample of humans or other animals, measure and count how long that pattern lasts, how may times it occurs, under what circumstances it appears, and when it is it likely to change. The scientist can also count the timing, duration, and number of particular actions within the pattern, at the microlevel (the kisses, hugs, nods, etc.). These can be counted separately for each partner, and statistical and simulation models can be used to verify the recurring stable patterns at the macrolevel. The danger, however, is that this method runs the risk of freezing the phenomenon, that is, of forgetting—after all is counted and analyzed—that patterns like greetings are sustained by a dynamic process.

The main thesis of this paper is that macroscopic order in dynamic systems emerges in the developing relationship between the constituents of the system and in the developing relationship between the observer and the system. Without taking account of these evolving relationships, quantification can lead to reductionism. Quantifying may lose the evolving process for the sake of trying to capture it. And when this has been done, and the paper published in a respectable quantitative empirical scientific journal, the scientist/observer has in fact affected the reader's understanding of the system by this mode of action on the system, which in the end, is the observer's choice and a point of view (Toren, 1996).

The result is analogous to trying to understand quantum mechanics by using Newtonian classical mechanics. Quantum mechanics, as a theory of the subatomic world, cannot serve as a theory of the macroscopic world of behavior. There is, however, an analogy between Heisenberg's uncertainty principle, and other "strange" quantum phenomena, and the behavioral science of dynamic systems. By ignoring the role of the observer, and by trying to impose the observer's (unacknowledged) perception of stability, we prematurely reify something that is inherently dynamic (because it is always changing).

Quantification per se, however, is not inherently concretizing and reifying if the observer recognizes that measurement is simply one way of engaging in a scientific relationship with a dynamic system. In this case, reduction to a quantity may be a useful scientific tool so long as this act is placed in the context of other convergent acts of meaning-making by the scientist. The dynamics of behavior, like the subatomic realm, is a strange world that shifts in the way it appears depending upon our point of view. Behavior is not an "it" or a "thing." Behavior constitutes itself in the very process of forming, acting, changing, and disappearing (Fogel, 1993; Morris, 2004). Scientific language can literally create a world. To use the scientific term, the noun "behavior" can easily create the illusion that there is a "thingness" to behavior, a substance, and a permanence.

The process of engagement with the written word in a scientific document is also emergent and dynamic. A sociocultural landscape of mutual linguistic understanding emerges (in the time frame of microseconds) when the reader engages with the text. Behavior is created as a dynamic moment of shared meaning. There is a further choice, however, taken by either the writer or the reader, to assume that what appears in this dynamic moment of shared understanding is therefore substantial and concrete. This turn toward reification is likely to better reflect the stance and judgment of the observer than the changing and dynamic reality of the system being observed.

This is not a discussion of the fictitious and imaginary, as if the noun were something like "hobbit." Behavior constitutes a domain we can call "reality," so long as we understand "reality" to be dynamically constituted, as alive and changing, and as different with respect to the point of view of the observer. This observation has the potential to be profoundly disturbing. On the one hand, few could deny that behavior is dynamically constituted, alive and changing, and that different people describe and interpret it in different ways. On the other hand, few people are likely to explicitly recognize or accept that, therefore, behavior, while real, is not a concrete thing at all.

In English, the verb *to know* generally leads to the formation of a concrete, factual body of knowledge. The verb *to understand*, however, refers to an open-ended, experiential, emotional process of knowing that usually occurs between people as they engage over time in close interindividual relationships. To *understand* in English is equivalent to *conocer* (Spanish), *conòscere* (Italian), *connaître* (French), and *conhecer* (Portuguese). The corresponding words for concrete knowing in these four languages are *saber, sapere, savoir*, and *saber*. Research on the dynamics of meaning-making admits to an inability to know completely (since behavior is changing in the very act of observing and conceptualizing), and instead seeks to engage in a long-term process that may lead to understanding.

The idea that one can have complete knowledge comes from ancient Greek thinking which became the foundation of Western science, what Levinas (1969) calls "totalizing." Philosophers of intersubjectivity (Buber, 1958; Jopling, 1993; Levinas, 1969), however, point out interindividual communication reflects what Levinas calls "infinitizing," meaning that we can never completely know another person or completely describe behavior. In an infinitizing stance toward the other, there is no sense of being directed or evaluated; only a feeling of union. One feels connected to the other and meets the other without reserve and in the fullness of the other's vulnerability to be changed. Buber (1958) called these types of relationships “I-Thou” as opposed to the totalizing stance of “I-It” relationships.

Scientists who take as the starting point the slipperiness and ineffability of the very dynamics that they wish to study may aspire to shed light on the underlying dynamics of behavior. No previous reification of behavior dynamics has succeeded in helping us understand why some people contract deadly diseases, why war and violence continue to flare in an enlightened global society, or why poverty and hunger are globally pervasive. Perhaps the answers lie in a dynamic understanding of how these problems develop over time. Perhaps there are no concrete answers, but rather a process of learning how to understand and work with our unimaginably complex universe.

The Conceptualization of Change in Dynamic Systems Theory

In the end, the scientist/observer concerned with illuminating and respecting the inherent dynamics of the system is compelled to shift away from a study of structure to a study of process (Capra, 1996). One way out of the dilemma of conceptualizing behavior as a thing is to replace the noun with a verb, “behaving.” Whether noun or verb, naming may eventually lead to reification. Shifting to a verb, however, can be a useful linguistic trope to remind us that the nature of systems is change, and that stability is in the eye of the beholder. Reading and studying dynamic systems requires an active, inquisitive, and critical meta-awareness that the linguistic and mathematical devices of science serve only as signifiers for that which cannot be completely signified. This paper is meant to be read with that type of meta-awareness.

The admonition that “the map is not the territory,” does not quite fit here since the territory is typically seen as fixed. But territory changes with earthquakes, storms and floods. A more radical shift (change) in the scientific stance is called for: from things-in-themselves to transformations. Territory implies space and boundaries. Transformations imply time and change. As a prelude to the description of research methodology, in the following section, three levels of change are discussed. These are derived from research using the techniques to be presented in this paper.

Sequence vs. Process at the Microlevel (Level 1 Change)

Change at the microlevel involves a shift from one to another behavior within an attractor. In mother-infant face-to-face play, for example, there is an iterative cycling in both mother and infant of smiling and not smiling, mutual gaze and gaze elsewhere, and other body movements and facial expressions typical of this type of play. Changes occur as the dyad shifts from one to another mutual action. Each instance of this attractor that recurs over days or weeks also has a similar pattern of activity, yet it is changed from the previous instance of this attractor. These microlevel changes are referred to as Level 1 change, or ordinary variability within a stable attractor (Fogel, Garvey, Hsu, & West-Stroming, 2006a).

Virtually all studies of microlevel change in the behavioral sciences reduce the flow over time to a probabilistic sequence. Sequences have the form of A → B → C. This scheme can become very complex, as when the behavior of multiple interacting partners is tracked simultaneously. In this case, the behavior of each partner can be observed to precede, follow, or be simultaneous with the other. A wide variety of statistical and simulation models exists to conceptualize and analyze these sequences for regularly recurring patterns. These tools have continued to become more mathematically sophisticated, capable of describing complex lead-lag relationships, timing factors in interaction, and other quantitative indices of social engagement and sensitivity (cf. Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001; Lewis, Lamey, & Douglas, 1999; Ryan, Gottman, Murray, Carrère, & Swanson, 2000; van Geert, 1998).

The use of any of these tools, however, can imply a reification of change is a linear sequence. This is because, once coded and statistically analyzed, significant probabilities capture attention. The underlying dynamics are messier and less easy to understand and remember. But if behavior at any level of description is always changing, and if those changes occur in the process of forming the relationships that ultimately constitute the perceived attractor, then models of sequence, however, sophisticated, may miss the very dynamics they presume to describe.

In research by the author and his colleagues, we have reported sequential data of the following sort: Infant smiles are more likely occur during maternal smiles; infant smiling tends to follow maternal smiling up until 4 months, after which infants begin to smile in anticipation of the mother's smile; infant smiles are more likely to occur in particular contexts and not others (e.g., in the climax rather than the setup of a peek-a-boo game) (Fogel, Nelson-Goens, Hsu, & Shapiro, 2000; Messinger, Fogel, & Dickson, 2001). On the other hand, we have published qualitative research on mother-infant smiling that shows how highly variable such sequences can be. Not only that, facial forms of smiling, barely noticeable differences in the "intonation" of the expression but meaningful to the participants, reflect the playfulness and creativity of the underlying dynamics (Fogel, Nwokah, & Karns, 1993; Pantoja, Nelson-Goens, & Fogel, 2001). Neither of these descriptions is the "right" or "correct" one. Rather, they reflect different points of view of the observers and different processes of engagement with the data: one more quantitative and the other more qualitative.

Our research attests that process is much more dynamic and more difficult to describe than structure. No behavior emerges fully formed from the brain without being subject to conditions in the periphery of the body and in the local environment in the very act of formation (Thelen & Smith, 1994). Words, gestures, and expressions can be altered in their shape, intonation, size, explicitness, duration, clarity, force, and on many other dimensions depending upon the ongoing and simultaneous flow of communicative actions. This is the so-called *continuous process model of communication*, which is contrasted with a discrete state model of communication that is based on sequence rather than process (Fogel, 1993; King, 2004; Shanker & King, 2002).

These co-dynamics cannot always be modeled as a linear sequence. This is because, in some cases, communication functions via *information* (i.e., meaning-making) rather than by a computation of physical or temporal parameters (Pattee, 1987). Facial expressions, for example, dynamically alter the behavior of social partners. A tiny facial movement requiring little energy can induce large expenditures of movement energy in the social partner, as when a smile elicits a partner's heart rate change and initiates movements of approach. Intracellular communication via the different sequences of bases in DNA and neural communication via different neurotransmitters are other examples of informational dynamic systems (Capra, 1996; Oyama, 1985; Pattee, 1987).

This information approach has an emphasis on the mutuality between constituents which change as they enter into relational processes, altering their identities in order to establish the ground for a relationship. A facial expression, such as a smile, does not contain discrete information about the smiler. Rather, the meaning of the smile depends upon the relationship between the smiler and the partner. People do not typically smile unless the partner is perceived as receptive to opening that line of emotional communication.

In digital and electronic systems, information is usually thought of as discrete bits having a concrete value (either "on" or "off" in a binary system typical of most computers). A dynamic system, however, requires a completely different conceptualization of information that is not fixed in advance and not "transmitted." Rather, information is created in the process of communication and is always dynamically related to the current state of the entire developing system (Fogel, 1993; Oyama, 1985). In other words, meaning making is the outcome of a finite process of engagement.

In another example, long-term social partners develop between them informational attractors involving unique patterns of speech and expression not shared outside the relationship. Words and gestures of endearment for a romantic couple (sweetie, lover, honey, etc.) mean (are informed by) the entire history of their communication, recreating particular feelings and perhaps further states of intimacy. Yet, words and gestures are not fixed in form and usage. "Honey" can be spoken with love, anger, or impatience depending dynamically on the situation. "Honey," while meaningful to the partners, does not always mean the same thing because the information is created in the moment of dynamically unfolding feelings and actions.

Sequence vs. Process at the Macrolevel (Level 2 Change)

Attractors at the macrolevel grow out of these co-dynamics at the microlevel and reflect qualitatively different modes of system organization (Kelso, 2000). Furthermore, one of the tenets of dynamic systems theory is that out of ordinary variability (Level 1 change), there sometimes arise changes that are more salient, different, or innovative (Level 2 change). Changes at Level 2 are innovations, perceived as different from the ordinary variability of Level 1 change. Innovations are changes that play a different role in the complex system than ordinary variability. They may precipitate a change from one attractor to another, or even a developmental change (Level 3 change, see below) in the entire system of attractors (Fogel et al., 2006a; Thelen & Smith, 1994).

No simple numerical index can fully describe the transition from one attractor to another. The collective behavior of the states of H_2O (i.e., ice, water, and steam) differ in quality. Ice has crystals and water does not. Water and steam have dynamic flow patterns and stable ice does not. Although the different states can be represented by a quantitative parameter, temperature or energy, this parameter does not in any way describe the complex dynamics at the micro- and macrolevels that constitute the different states and the ways in which one state changes into another.

From a quantitative perspective, when a dynamic system is in a stable attractor, it is in an energetically conservative mode where it maintains its stability. In order to change from one attractor to another, for the system to re-organize, energy is required to move the system from this stable state. As water is heated, for example, there is an increasing disorganization of the water's movements, a relatively chaotic state. At some point, however, boiling water begins to form rolling patterns, a Level 2 change, that more efficiently move the heat energy from the bottom of the vessel to the surface of the water where it can convert to steam. The water finds a new pattern of self-organization that most effectively dissipates the heat energy. In this kind of dissipative system, new patterns of order—attractors—emerge as systems seek to conserve and release energy in far from equilibrium states (Capra, 1996).

Because the ordinary variability (Level 1 change) of the microlevel system within an attractor is dynamically changing in realtime, an innovation (Level 2 change) is a "change in the pattern of change." In informational terms, systems make transitions when the change in the pattern of change is noticeable, that is, the change becomes informative or meaningful to the constituents (Pattee, 1987). Information about system change does not exist prior to the change, but rather is created in the moment when a system "notices" a difference, what has been described in informational terms as "a difference that makes a difference" (Bateson, 1975; Oyama, 1985).

Couples in a romantic courtship or dating relationship, for example, may maintain a dynamically stable ordinary variability without any talk of a more serious commitment. When such talk begins—about exclusivity or about marriage—it makes a very big difference for the conduct of the ongoing ordinary variability. This innovation is most likely to be germinated in the ordinary variability of the courtship relationship, as partners may seek to make long-term meaning out of everyday exchanges. The system begins to shift toward another kind of talk about that longer term commitment. Once that new kind of talk is established, it becomes a new kind of ordinary variability from which further innovations can be launched.

Sequence vs. Process in Developmental Change (Level 3 Change)

Developmental change is yet another level of the change process in social and behavioral systems, designated as Level 3 (Fogel et al., 2006a). At any given time, a social behavioral system has a finite number of different attractors, such as different types of play in the parent-child relationship. In development, the entire system of attractors—the collective behavior of the system as a whole—changes. Developmental change is the creation of new attractor patterns and the loss of others. Development is the destabilization, re-organization, and re-stabilization of the collective system of historical attractors (Fogel, 1993; Fogel et al., 2006a; Lewis, 1995; Thelen & Smith, 1994).

Another basic tenet of dynamic systems theory is that changes at the developmental level grow out of changes at the micro- and macrolevels that occur through variations and innovations. Some of these variations may increase the level of energy or informational variability beyond the boundaries of the existing attractors. These innovative variations often occur spontaneously, such that development emerges from the activity of the system itself (Fogel et al., 2006a; Thelen & Smith, 1994; van Geert, 1998). Dynamic systems, in other words, are historical. The available set of attractors serves as resources for the system to create opportunities for developmental change. The same idea is contained in Piaget's (1954) thinking: that some chance discovery may eventually change the existing system of schemes via assimilation and accommodation.

The problem of the emergence of new forms is at the very core of developmental inquiry. How does something new emerge from something that has been there in relatively stable form? Dynamic systems theory recognizes the emergence of innovation or novelty as a fundamental feature of complex systems. Non-biological systems, such as chemical reactions and the physical universe, develop over time because novel variability provokes the system into new stable attractors that are neither planned nor preprogrammed (Laszlo, 2001; Prigogine & Stengers, 1984; Weimer, 1987). A growing number of thinkers have embraced the idea that spontaneous emergence is at the heart of behavioral and psychological change. In the behavioral sciences, this concept has also been called discovery, creativity, construction of novelty, and transformation (Carvalho & Pedrosa, 1998; Eckerman, 1993; Fogel, 1993; Gottlieb, 1992; 2003; Lewis, 1995; Lock, 1980, 2000; Lyra, 1998; Mahoney & Moes, 1997; Nelson, 1997; Overton, 2002; Schore, 2003; Stern, 1998; Thelen & Smith, 1994; Tronick, 1998; Valsiner, 1997; 2001).

The indeterminacy in dynamic systems can produce historically unique trajectories that partly account for the formation of individual differences (Fogel, 1990; Fogel & Branco, 1997; Fogel, Lyra, & Valsiner, 1997; van Geert, 1997; Kellert, 1993; Thelen, 1990; Valsiner, 1997). Informational approaches to dynamic systems perspectives can help us understand why historical changes in people, groups, or societies can never exactly repeat, why every social system is unique, and why these differences are contingent on the dynamics of the communication process and not always amenable to prediction (Fogel, Lyra, & Valsiner, 1997; Gould, 1977).

Dynamic Systems Methods for the Study of System Change

The focus of dynamic systems theory is change. Research questions about change dynamics can be formulated at all three levels of change. For any level, one can ask: How does change occur? What mechanisms produce change? What conditions are likely to promote the emergence of change? These questions may be cast in terms of basic or applied research. Basic research might seek to uncover the processes of change in naturally occurring social systems. Applied research—as in international policy, therapeutic intervention, or education—may seek to uncover the basic principles of change in order to promote desired changes in a system and avoid undesired changes.

Questions may be framed about the stability vs. instability of new attractor patterns that emerge as a consequence of a naturally occurring or induced change process. Educationally or therapeutically induced changes that do not last are less desirable than ones that can be sustained over time. Research can seek to uncover the processes that create lasting change as well as the processes that maintain systems in desirable states.

Does the emergence of new behavior patterns tend to suppress the old patterns or to coexist with them? If a person is relieved of a phobic disorder or alcoholism through therapy, is that phobia still lurking somewhere, ready to be reactivated under particular environmental conditions? When a peace between warring nations is negotiated, under what conditions will that peace last, and is there any likelihood that old hostilities will re-appear?

Microgenetic Research Designs

The hallmark of dynamic systems research is the study of change *while* it is occurring, instead of merely comparing "before" and "after" observations. The primary tool for doing change research from a dynamic systems perspective is the microgenetic research design (Fogel et al., 2006a; Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005; Siegler, 1996). Microgenetic research designs are specifically intended to allow the researcher to closely observe processes of change, instead of products or outcomes. Typically, some period is selected in which the system is expected to undergo a Level 2 or Level 3 change. Then observations are made on particular cases relatively frequently before, during, and after the change in order to observe the relevant Level 1 changes that may contribute to the Level 2 or 3 change (see Figure 1).

Regardless of the researchers' theoretical perspectives and the developmental domains under investigation, microgenetic designs are defined by the following key characteristics:

- Cases (particular systems of interest) are observed through a period of developmental change.
- Observations are conducted before, during, and after a period during which rapid change in a particular domain occurs. That is, observation is not simply con-

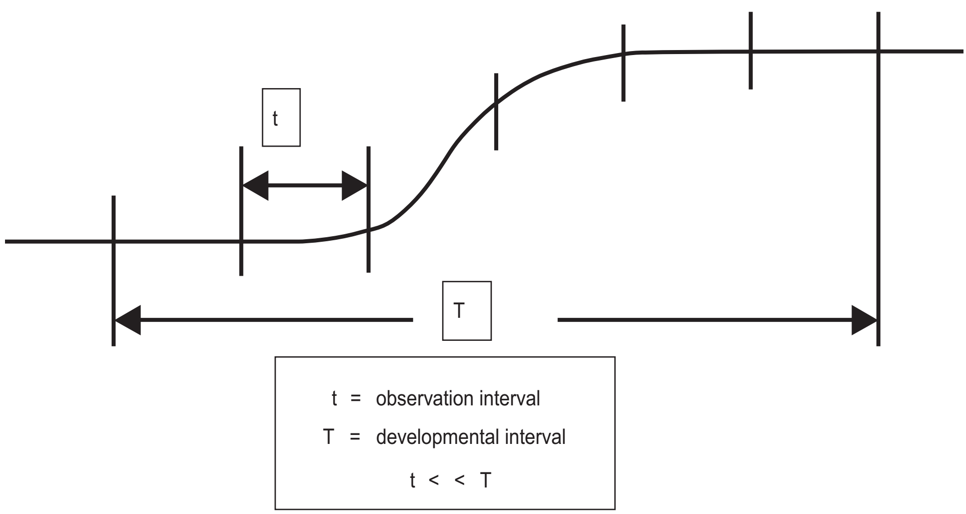

FIGURE 1.

ducted before and after the change takes place. The change may be a spontaneous developmental change or it may be a planned intervention.

- There is an elevated density of observations within the transition period. That is, observations are conducted at time intervals that are considerably shorter than the time intervals required for the developmental change to occur. For instance, if a developmental change takes place over several months, then observations should be conducted weekly or even more frequently.
- Observed behaviors are intensively analyzed, both qualitatively and quantitatively, with the goal of identifying the historical processes that give rise to the developmental change.

The unit of analysis is one of the types of systems described earlier: intraindividual, interindividual, ecological, and sociocultural. In the interindividual system, for example, as an individual develops, its relation to the external world changes, such that its effective environment—the actual physical, biological, and social factors with which it interacts—also changes. One of the challenges of systems research is to interpret the concept of environment in such a way that it incorporates an appropriately dynamic view of the changing relations between the developing individual and his or her context. This requires observation across representative developmental contexts to identify the range of behavioral capacities and developmental trends characteristic of the organism-environment system.

Microgenetic research has the advantage of being able to trace the historical development of change over time within the same system. The historical approach has been applied using microgenetic research designs (Bruner, 1983; Fogel, 1990; Fogel et al., 2006a; Granott & Parziale, 2002; Greenspan, 1997; King, 2004; Lavelli et al., 2005; Overton, 2002; Rosenwald & Ochberg, 1992; Shanker & King, 2002; Siegler & Crowley, 1991; Thelen & Smith, 1994; van Geert, 1998). These studies involve both quantitative tracking of developmental trajectories and qualitative analysis of life history narratives that reveal developmental shifts in shared information relative to new behavior coordinations in interindividual systems.

Recent advances have given dynamic systems scientists new tools for the study of change processes. There now exists a new class of statistical models called hierarchical linear models or multilevel models (Bryk & Raudenbush, 1992; Butt, Choi, & Jaeger, 2005; Prosser, Rasbash, & Goldstein, 1991) that allow researchers to examine developmental trajectories in microgenetic designs, made by tracking a key measure over frequent observations, for the group as a whole and for each individual. There have also been recent improvements in qualitative research methods, giving new credibility and rigor to the use of narrative descriptions of observed behavior and life history narratives (Denzin & Lincoln, 1994; Polkinghorne, 1995). These new quantitative and qualitative methods fit perfectly with the focus of dynamic systems on change over time in the qualitative macroscopic attractors.

In addition to observations of the natural evolution of systems, systems research often includes systematic experimental intervention or manipulation to uncover and identify the developmental resources necessary and sufficient to foster developmental change. In the intraindividual and interindividual systems, these resources include genes, cell and tissue interactions, sensory experience, diet and exercise, and social relations with conspecifics, to name but a few.

Dynamic systems experimental interventions or manipulations attempt to discover the differences that make an impact by following developing systems as they develop and add or subtract features of normally occurring experience or activity to identify those developmental resources and their relationships that are necessary and sufficient to foster change. These differences are hypothesized to be innovations that have the potential to alter the system. The key idea is that the experimental alteration must never be so drastic as to destroy the possibility for the system to transform over time. The following are examples of dynamic systems experimental procedures (Gottlieb & Lickliter, 2004; Lickliter & Honeycutt, 2003).

1. **Experiential attenuation** is when features of normally occurring experience are removed from the developmental context, allowing researchers to better identify how change is influenced by specific developmental resources in real time.
2. **Experiential enhancement** is when additional experience is added to the individual's developmental context. This can be done by experiential substitution, in which normally occurring experience is replaced with a different form of experience, or experiential displacement, in which the temporal relations between features of experience are shifted or rearranged to allow deeper insight into the history or process of specific reorganizations.

These types of manipulations and the evaluation of their consequences on developmental change are often used in parallel with one another to explore the complexity and contingency of developmental processes. Combining microgenetic observation, which documents the process of change, with experimental manipulation, which identifies the developmental resources contributing to change, provides a powerful method for identifying the conditions under which change is most likely to occur.

In summary, dynamic systems research:

1. seeks primarily to probe the systemic and simultaneous linkages in the network of relationships that sustain particular patterns of development over time;
2. aims to uncover the possible pathways that lead to changes in certain undesirable patterns; and
3. attempts to discover the processes required to sustain and foster the development and maintenance of a healthy developmental trajectory, or a more desirable network of relationships needed for effective decision-making and positive social change.

In intervention research, for example, systems don't get "fixed" or "cured" with a simple formula. Rather, the dysfunctional system must be allowed to transform slowly over time, systemically, into a more functional system. In dynamic systems science, we seek to understand the laws of transformation.

Qualitative Research and the Role of the Observer

In the traditional quantitative research paradigm, one constructs hypotheses at the beginning of the study, carries out the planned observational or experimental procedure on a randomly selected sample from the population, derives numerical or categorical measures, analyzes the data in a manner directly driven by the hypotheses, and makes an interpretation. If the original hypothesis needs to be altered, the researcher returns to the population to test another sample with a variant of the procedure, or to re-code the data based on a different set of observational categories.

One of the central principles of qualitative research, in contrast, is an iterative, cyclical approach to interpretation during the data sampling, coding, and analysis. Thus, hypotheses, methods, and interpretations inform each other and change each other as a process, creating an inductive spiral known as the hermeneutic circle (Bromley, 1986; Robson, 1993). The observer, neither naïve nor objective, becomes an informed and involved scientist. Hermeneutic approaches have been used in case study, ethnographic, rhetorical, phenomenological, feminist, and symbolic interactional methods in the humanities and behavioral sciences (Bernstein, 1983; von Eckartsberg, 1986; Erickson, 1992; Gaskins, 1994; Lather, 1991; McCall & Wittner, 1990; Rogoff, Mistry, Goncu, & Mosier, 1993; Schwandt, 1994).

The principles of qualitative research are similar to the principles of qualitative, informational dynamic systems. In qualitative research, the investigator is part of the system being studied and engages with the system itself or with the data recorded from the system. A dynamic system is continually in a process of change in which no part of the system is permanently objective or fixed. Even so, in a dynamic system, semi-stable attractors can persist as the system cycles through iterations that, from the observer's perspective, appear to be similar to each other. Similarly, there are no fixed hypotheses, categories, or conclusions in qualitative research. The qualitative scientist cycles iteratively through the data, each pass revealing a new working hypothesis and a new way to categorize. Yet eventually, *these working interpretations coalesce into a semi-stable model of the system*. The interpretation of the data becomes an attractor in a scientific system of information and communication. The iteration, interpretation, and revision continue until the observers feel confident of an emerging consistency and until new interpretations do not emerge during the process of reading and re-reading the data, which has been called the constant comparative method (Patton, 1990; Strauss & Corbin, 1990).

Credibility is a criterion used in qualitative research methods to evaluate whether the investigation successfully captures the meaning for the participants. Credibility parallels the notion of internal validity in quantitative methods. Observers are deemed more credible if they have a prolonged engagement with the data, the participants, and a record of persistent observation of the phenomenon under investigation (Denzin & Lincoln, 1994; Savage-Rumbaugh & Fields, 2000). Credibility is also enhanced if the investigators share excerpts of the original videos or transcriptions to allow the readers to make their own interpretations of the material (Rogoff et al., 1993).

These research methods are designed to create, via a meaning-making process, a semi-stable view of what is informative or meaningful for the participants in the social process. "The inquirer constructs a reading of the meaning-making process of the people he or she studies . . . The activity of understanding unfolds as one looks over one's respondents' shoulders at what they are doing" (Schwandt, 1994, p. 123).

Meaning making is equivalent to information creation in a qualitative dynamic system. To "make meaning" or to "create information" refers to the detection of a difference that makes a difference. How can scientists be assured that their interpretation of the subjects' meanings are in accord with those of the subjects? At issue is the extent to which the warrant for interpretation of participants' meaning is based on: (1) the investigator's subjective identification with the participants using empathy, (2) the investigator's construction of the participants' meaning system within their own sociocultural context, or (3) the investigator's linking of the interpretation of a particular case with the history of interpretations of other such cases within the literary genre that defines the investigator's field of inquiry (Bradley, 1994; Jansen & Peshkin, 1992; Keegan & Gruber, 1994; Schwandt, 1994; Toren, 1996).

In practice, qualitative research involves all three of these warranting procedures. Empathy is used, but it has a limit as a scientific tool since our participants are not the same as ourselves. Observers "can only approximate others' experiences and so gain only limited access to their knowledge" (Belenky, Clinchy, Goldberger, & Tarule, 1986, p. 113). This sense of incompleteness, the inability to fully define and categorize another person, "marks the tragic, perpetually inadequate aspect of social research" (Reinharz, 1984, p. 365). This is perhaps especially the case when we study non-verbal infants, non-human animals, or people from very different cultures.

The limits of empathy point out the tragic fragility of scientific interpretations of behavior and stand in sharp contrast to the hubris of objectivist approaches. In the objectivist approach, the measures of individuals and groups are presumed to accurately stand for the real thing. What's more, the appeal to a value-free, objective science adds to the warrant for making subjects of research into objects of study, less than fully alive beings. The qualitative scientist, by admitting the limits of inquiry and the indeterminacy of the findings, may seem weak and non-scientific by comparison.

Qualitative research, however, is a demanding exercise in *not knowing*, a deliberate attempt to hold back from premature interpretation and to capture the process of emergence. By making a conscious choice to stand outside of the objectivity of method, the qualitative scientist becomes a living part of the system. At the risk of seeming biased, qualitative researchers opt to expose the inherent dynamics of the social process. They accept as truth that which emerges from a process, and they see their own work as a reflection of the way in which the universe actually operates. Qualitative investigators can rely on the literature in their field only so far because much of that work is done from a normative and seemingly objective point of view.

There are also limits to the researchers' ability to step outside their own sociocultural and disciplinary point of view. The key to successful qualitative research, however, is to clarify one's limitations and to engage in an active meaning-making process by which those perspectives and limitations are clarified. Again, the goal is not some ideal answer or result, but rather to engage in a process of meaning making that is likely to converge on an emergent description of the data. That description is accompanied by a description of the limits of the observer, as well as evidence for their credibility.

Research Example

It is difficult to present a complete dynamic systems research example in the short space of this paper. Many more detailed examples of qualitative dynamic systems research using these principles can be found in Fogel et al. (2006a), King (2004), and Fogel, King, & Shanker (2006). In addition, a description of applied dynamic systems research methods is given in Fogel, Greenspan, King, Lickliter, Reygadas, Shanker & Toren (2006).

Here, an excerpt is presented from Fogel et al. (2006a) that illustrates the description of a developmental (Level 3) change in one mother-infant dyad during the period between 2 and 6 months. The attractors of interindividual relationships are regularly recurring patterns of communication called frames. Frames are segments of co-action that have a coherent theme, that take place in a specific location, and that involve particular forms of mutual co-orientation between participants. Because frames recur repeatedly over weeks and months, they have the features of an attractor in a dynamic system since they are reconstituted dynamically and dyadically on each reappearance. Frames are semi-stable, lasting for only a finite period in an interindividual relationship. They emerge at one point in time and dissolve or disappear at another point in time. In a romantic partnership, for example, engagement or betrothal is a frame that has a limited time of life between courtship and marriage.

The communication between the 13 mother-infant dyads in this study was videotaped weekly during the 4-month observation period, meeting the conditions for a microgenetic research design (Figure 1). These videos were coded into four mutually exclusive and exhaustive relationship frames. The social frame was coded when the topic of communication was face-to-face play without objects. The guided object frame was coded when the mother took an active role in demonstrating and scaffolding the infant's use of objects. The non-guided object frame was coded when the infant played with objects without the mother's direct assistance but with her ongoing attention and verbal commentary. The social-object mixed frame was coded when elements both of face-to-face play and guided-object play appeared at the same time, as when a mother used a toy to touch the infant's face or body while vocalizing in an expressive manner typical of the social frame.

The durations of each of the frames, measured as a percentage of time in the observation session (sessions lasted 10 minutes) is shown graphically in Figure 2 for one dyad, Betsy and her mother. Notice that the durations of the social and the guided-object frames decline over this period, while the not-guided-object frame and the social-object mixed frame increase in duration.

In this example, the focus is on the sessions in which developmental change is most rapidly occurring, sessions 7 and 8, in which Betsy is 17 and 19 weeks old. During session 6, Betsy for the first time reaches for an object while looking at it. In session 7, the social frame declines dramatically. Betsy continues to look at her mother and smile during the other frames, thereby maintaining a connection with her mother, and thus blending the social frame into the other frames. This is seen especially in the rapid increase in duration of the social-object mixed frame. Sessions 7 and 8 are the first time that the not-guided object frame emerges as an entirely new frame, separate from the other object-related frames, in which Betsy explores objects without the mother's assistance (as in the guided object and social-object mixed frame).

With the increasing growth of the not-guided-object frame, the guided-object frame, while actually declining quantitatively over time, continues to develop qualita-

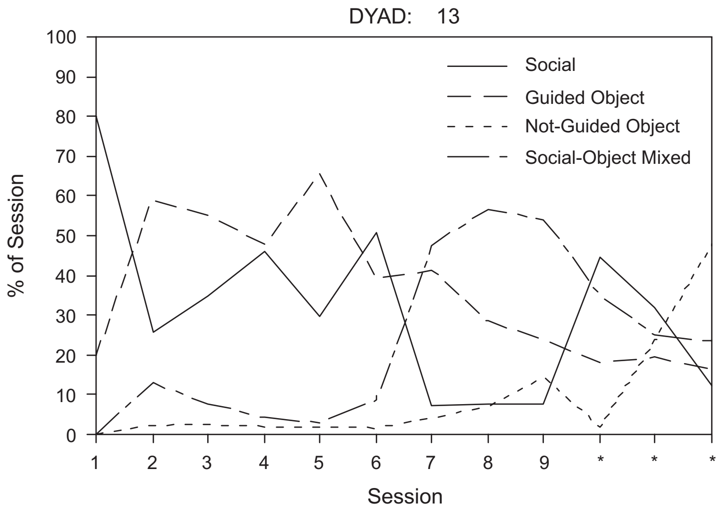

FIGURE 2.

tively. The mother, for example, gives Betsy certain objects and helps her hold them when needed.

> The not-guided-object frame and the guided-object frame now occur in quick succession. Object manipulation follows a sequence composed of: Betsy actively mouthing an object (i.e., the not-guided-object frame), the mother introducing a new object to Betsy followed by Betsy reaching for and grasping the new object (i.e., the guided-object frame), and then Betsy manipulating the second object, at times actively mouthing it (i.e., the not-guided-object frame). This sequential patterning between the guided-object and the not-guided-object frames appears to constitute a form of historical recapitulation in which an already existing historical frame (i.e., the guided-object frame) is maintained and makes transitions with a newly emergent frame (i.e., not-guided-object frame).
>
> Now that Betsy is becoming more skilled at manipulating objects on her own, a new ordinary variability characterizing the social-object mixed frame also emerges during visits 7 and 8. The mother now uses the object Betsy is holding, making it kiss Betsy's face without taking the object from her. It is as if Betsy is playing the object-touch games herself. Both Betsy and her mother are also becoming more serious, smiling and laughing relatively little and producing fewer vocalizations. The mother, for instance, uses far fewer sound effects with objects during visits 7 and 8. The impression the observer gets is that the social-object mixed frame is gradually becoming transformed as the not-guided-object frame emerges as a new and distinct frame. In fact, certain characteristics of the not-guided-object frame (such as helping Betsy play the object-touch games herself) appear to permeate the social-object mixed frame. (Fogel et al., 2006a)

These two sessions not only show a quantitative change in the frame durations, but there was also a qualitative change in the pattern of organization, both at the microlevel within the frames and the macrolevel of sequencing between the frames for Betsy and her mother. This complex system of linked changes constitutes a developmental (Level 3) change. The developmental change is not merely in the fact that the not-guided-object frame emerges for the first time, but rather because the whole system of frames seems to shape-shift in order to give birth to the new frame. All these changes are occurring simultaneously, as a dynamic process rather than a simple sequence.

> The not-guided-object frame begins to pervade these sessions with the "support" of the guided-object frame and the social-object mixed frame. Compared to previous sessions, all of the observed frames (i.e., not-guided-object frame, guided-object frame, and social-object mixed frame) undergo coordinated changes as reflected by the emergence of a new ordinary variability for each of these frames. Specifically, as Betsy becomes more object-focused and fascinated with the new activity of examining the objects around her, the mother adjusts her object-oriented behaviors and begins providing support to her infant's object exploration by handing them to Betsy.
>
> The not-guided-object frame begins to become elaborated into a fully developed frame as Betsy spends increasing amounts of time manipulating objects. This constitutes a newly emergent frame that arises out of the innovations (Level 2 change: the mother places objects in Betsy's hands) within the guided-object frame and social-object mixed frame during sessions 4, 5, and 6. At the same time, the guided-object frame expands its forms as illustrated by the increasing variability in the way the mother presents objects to Betsy. The social-object mixed frame also changes from its earlier quality of enjoyable social play to becoming more focused on Betsy's more serious examination of objects.
>
> Furthermore, the dyad's new ordinary variability (Level 1 change) during sessions 7 and 8 includes a patterned integration of the guided-object frame and the not-guided-object frame. In this case, it is as if frames (i.e., guided-object frame and not-guided object frame) are blending together at the same time that a historical dynamic is recapitulated by the dyad.
>
> All of these processes—the simultaneous re-organization of each of the frames in relation to each other and the emergence of a new frame in the context of the blending and recapitulation of frames—constitute what we consider to be the conditions of a developmental change (Level 3 change). Innovations (Level 2 change), as seeds for developmental change, alter the ordinary variability within frames on later occasions. This alteration, however, is of the same kind as the innovation when the infant becomes more active across multiple modalities. In the case of this developmental change, however, the entire pattern of communication changes across the whole system: all the frames and transitions are involved. For reasons we do not yet understand, the build-up and elaboration of innovations seems to reach a critical point at which time the "old" or historical system can no longer contain the innovations within ordinary variability. At this time, the system spontaneously shifts to a new system-wide organization that includes new frames, creative blending of old frames, and new actions within frames. It is important to note that we did not observe any single innovation or event that precipitated the developmental transition. (Fogel et al., 2006a)

Although the more detailed account cannot be given here, this excerpt shows the focus on history and meaning, the role of the observer, and the complexity of the co-actions across all three levels of change in the system. It also shows that a qualitative analysis provides something that cannot be gleaned from the quantitative description alone. The two methods, quantitative and qualitative, support and complement each other as a description of the developmental change process.

Conclusions and Implications

If dynamic social systems are fluid, changing, emergent, and yield created information in a meaning-making process, then dynamic systems research best serves scientific discovery by substantiating these same processes in the method. Applying the standards of research objectivity, with fixed measures and *a priori* hypotheses can only limit and diminish the phenomenon under study. As a complement to qualitative investigation, quantitative measures can enhance and deepen our understanding of systems phenomena. Quantitative measurement and statistical analyses are seen as one way of understanding, rather than the only way of understanding. Qualitative systems research seeks to place the scientist in the system, not knowing the answer. To become a credible witness, the scientist works toward an emergent understanding, allowing the reader to be part of the discovery process. In the end, the scientist and the reader understand more, while remaining immersed in the boundless possibilities of not knowing.

The closest disciplines to qualitative dynamic systems research are history, biography, and narrative analysis. The historian tracks multiple and related processes (frames) through time and attempts to understand how their co-actions and co-changes illuminate, say, the processes occurring at the beginning or ending of a war. Dynamic systems research can add to this enterprise by the use of the qualitative and quantitative methods and the explicit decomposition of the system into levels of change, as described in the above example.

Dynamic systems are inherently not predictable. The start or end of every war is different because the co-dynamics are always different and changing. Once a system enters into a developmental change period, as in sessions 7 and 8 in the above example, change is often rapid, spontaneous, unpredictable, and probably unstoppable. Notice in Figure 2 that the developmental shift occurs in only 2 or 3 sessions. In the periods before and after sessions 7 and 8, the durations of the frames remain relatively stable.

Developmental change carries a certain momentum such that once the system reaches a critical point, there is no turning back. On the other hand, in the larger study of which this example is a part (cf., Fogel et al., 2006a), we found in all of our dyads signatures of the impending change process in the weeks before it actually occurred: the innovations that began to shake the system loose from its ordinary variability.

If this research model could be applied to social, economic, and political change on a set of national and international cases, to take one example, it may be possible to uncover the underlying dynamics that foreshadow (but not predict) a more precipitous change. Once some of these predisposing factors are identified in naturalistic studies, dynamic systems experiments could be done in which those factors are attenuated or enhanced to diminish the likelihood of less desired subsequent changes and to enhance the likelihood of more desired ones.

The same model of research could be applied to therapeutic and educational interventions, to the emergence of famine, to epidemics and other health crises, and to the deterioration and wellness processes of the human body. The hope is to discover the laws of change and the dynamics of transformation. How much can a system take before it breaks down? What is the process by which transformation occurs? Can developmental change be facilitated even during the rapid (and presumably irreversible) period of change, or only earlier during the pre-change period? Why do some individuals and systems seem to resist change and others embrace change? What are the differences that make a difference for a developmental change in any particular system?

The tools are now available to address these types of research questions, but these methods are slower and cost more than conventional research. This is because it is necessary to wait for the change to unfold, and many observations must be made in order to track the change process. The gain in understanding, however, is likely to be high.

Qualitative dynamic systems research is ideal for translational applications. Models that are expressed in terms of statistical interactions between quantitative variables are probabilistic and often far removed from the everyday process of meaning making as a social system. New models and interventions that rely on an understanding of the informational dynamics of the change process could be immediately applied to the work of practitioners and participants because these models are expressed in terms of the meanings that are already present in the system.

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