

**AT THE EDGE OF CHAOS:
A NEW PARADIGM FOR SOCIAL WORK?**

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Feb. 22, 1999

Published in:
Hudson, C.G. (2000, Spring/Summer). At the edge of chaos: A new paradigm for social work?
Journal of Social Work Education, 36, 2, pp. 215-230.

ABSTRACT

The search for a unified conceptual framework for social work has floundered as the profession has struggled with general systems theory (GST), and most recently, the eco-systems perspective. At the same time, social work has ignored chaos or complex systems theory which is not only the successor to GST, but some believe, is the third major scientific revolution of the 20th Century, following relativity and quantum theories. This article reviews key concepts and applications of chaos theory in the context of the general systems perspective and concludes that although it is premature to declare that chaos theory represents a new paradigm for social work, it promises to solve many of the problems posed by the now dated general systems approach.

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**KEY WORDS:** Chaos theory; Paradigm; Edge of chaos; Complex systems theory; General systems theory

## AT THE EDGE OF CHAOS: A NEW PARADIGM FOR SOCIAL WORK?

*A little neglect may breed mischief: for want of a nail the shoe was lost;  
for want of a shoe the horse was lost; and for want of a horse the rider was lost  
[for want of a rider the battle was lost, and for want of a victory, the nation was lost.]<sup>1</sup>  
Benjamin Franklin*

For many years now social work has sought a unifying conceptual framework to guide its practice, but has made only limited progress. Contributing to this slow progress has been the introduction of general systems theory to social work in the 1960s, and its amalgamation with the ecological approach in the 1980s. Despite the promise of these approaches, their application has been sporadic, and their coverage by schools of social work generally superficial. This can be attributed to a growing insularity in social work, and a reluctance to incorporate recent developments in allied fields. One such development is complex systems theory, more popularly known as chaos theory, which has evolved since the mid-1970s as the successor to general systems theory (see Çambel, 1993; Gleick, 1987; Lewin, 1992). Enthusiasts for chaos theory have gone so far as to argue that the Twentieth century has seen three major scientific revolutions--relativity, quantum, and most recently, chaos theory (Gleick, 1987; Rossi, 1989; Dresdan, 1992)--yet much of social work research and theory continues to draw heavily from general systems theory and even older paradigms. It is, therefore, the aim of this article to not only review the modest contributions of general systems and ecological theory, but also to consider the key contributions and promise of chaos theory, and more generally, complex systems theory, in advancing this conceptual framework beyond the eco-systems perspective.

### General Systems Theory Revisited

Social workers have for long been attracted to notion of the “total situation” of their clients, a term first coined by Ada Sheffield (1937). For this reason, they have often drawn on the concept of a system as defined by Ludwig von Bertalanffy as “a complex of components in mutual interaction...Concepts and principles of systems theory are not limited to material systems, but can be applied to any [whole] consisting of interacting [components]” (1974) and which laid the foundation for the development of general systems theory (GST). The theory represented an attempt to integrate the perspectives and findings from such diverse fields as the organismic social theories of the 19<sup>th</sup> century, the social survey movement, human ecology, information theory, and cybernetics (Leighninger, 1977; Siporin, 1980). Although the concept of general systems theory was initially presented in 1937, and first published in 1945 (Hearn, 1979), it was not until the 1950s that it was popularized in psychology by James G. Miller (1955), and subsequently introduced to social work by Gordon Hearn (1979). Then, in the 1960s, general systems attained a level of popularity in social work, mostly through the contributions of family systems therapy as well as the community mental health movement (Siporin, 1980). The 1970s saw a substantial growth in the applications of GST in the profession, as numerous social work texts began to include the perspective.

By the late 1970s discontent had been increasingly aired about the wholesale and uncritical adoption of general systems theory, especially on the part of social work educators (Drover & Schragge, 1977; Leighninger, 1977; Siporin, 1980). While many commentators have complained that GST is far too abstract to inform practice, the usual rejoinder is that it is actually a ‘meta-theory’, intended to guide the selection and application of more specific theories such as ego psychology or learning theory. This defense is not entirely convincing since the usual repertoire of concepts taught as part of GST provide few criteria for ordering relations among systems (Drover and Schragge, 1977, 32). GST often emphasizes a hierarchy of systems and subsystems, however, the usual summaries of the theory provide no basis or technique for disentangling

the plethora of feedback loops which typically link these systems. Similarly, Drover and Schragge point out the limited explanatory power of GST, suggesting that the difficulties which diminish its power include problems in optimization, ideological assumptions, isomorphic issues such as the assumption that most systems are the same, as well as the generality of the theory (1977). For this reason, unintended and negative consequences have been too commonly the result of programs of planned systemic change (Siporin, 1980). These problems are in many respects a reflection of a failure of social workers to move beyond the broad conceptual application of the theory, to use a range of practical techniques for investigating and simulating systems, such as those used in the field of system dynamics. An exception is Ann Hartmann's popularization of eco-maps.

Perhaps one of the most serious criticisms of GST is the problem of "assumed equilibrium" (Leighninger, 1977, 47), which refers to a tendency of many proponents of GST to over-emphasize system maintenance functions and negative feedback loops, as exemplified by the action of the thermostat, in perpetuating current modes of adaptation. Although such an assumption is by no means fundamental to GST, to the extent that its proponents interpret the theory in this regard they have tended to look outside systems for the challenges and sources of change and growth, rather than inside systems, whether these involve individuals or organizations. And for this reason, Kahn pointed out that, "Proponents of decentralization, community, and participatory control could find their activities in conflict with a systems emphasis." (Kahn, J.K., 1973, 43). One of the sources of this interpretation of GST, besides ideology, is a misunderstanding and minimization of what are referred to as positive feedback loops, those which amplify small changes, for better or worse.

Another criticism of GST is that too great a level of rationality is expected on the part of its users (Siporin, 1980). For example, Drover and Schragge (1977) complain that even in a relatively simple situation with 20 key systems, over a million possible relationships are created. Furthermore, when each set of actors brings a different set of goals and values, the problem of optimizing the common good becomes completely intractable. Others such as Siporin share the same concerns, but point out that in an eco-systems approach, it becomes easier to consider subjective experience, meaning, and value.

Because most social work renditions of GST are marred by the problem of "assumed equilibrium" and a lack of operationalization, it is not surprising that so many complain of the limitations of the theory in dealing with change and growth (Drover & Schragge, 1977; Halsz, 1995; Loye & Eisler, 1987), as well as generating directions for practice. On one hand, Drover and Schragge point out that GST promotes a technical practitioner role, which depoliticizes practice, thereby promoting conservative and individualistic tendencies in the profession (1977). Similarly, others see it as reinforcing individual practice, promoting the primacy of transactional, 'goodness-of-fit', and equilibrium-based solutions between individuals and their social environments.

In the 1980s, criticism of GST, from both the left and right, undercut but failed to extinguish interest in the theory. By the mid-1980s, De Hoyos and Jensen were able to argue that three distinct versions of systems theory had emerged (1985). First, Parsonian functionalism, they argue had all the while been an important but neglected option, one which had recently seen some renewed interest. Second, GST, as popularized by Gordon Hearn, has seen ebbing interest for many of the reasons discussed. Third and most significant, has been the amalgamation of GST concepts with the ideas from human ecology. This approach has been most commonly associated with Carel Germaine, as well as Max Siporin, one which has been traced back by some to Social Darwinism, and more recently, to Kurt Lewin's field theory. It focuses not so much on change, but on individuals abilities to negotiate and compromise with their social environment (De Hoyos and Jensen, 1985). While the comparison with Social Darwinism may seem harsh, as long as the sources of

change are seen as external to the individual, the concept of social selection, derived from that of natural selection ('survival of the fittest'), unmodified by more current concepts of emergence or self-organization from complex systems theory, will continue to underlie the thinking of some practitioners. Despite these limitations, the integration of systems and ecological theory represents an important advance, especially as the problem of 'assumed equilibrium' appears to be ameliorated (see Siporin, 1980, 509).

General systems theory, thus, has undergone significant permutations since its initial introduction in social work. While in its early years, it attracted not only those who sought a meta-theory for bringing the profession together (De Hoyos and Jensen, 1985), but also those who sought an alternative to the medical model and a conceptual foundation for macro-practice (Leighninger, 1977). But increasingly, especially as GST has been introduced to direct service practitioners through both the family systems field and ego psychologists such as Polansky, GST has come to be seen as a way of expanding the medical model to include the client's social environment (De Hoyos and Jensen, 1985). The theory has become co-opted by those whose primary interest is the stabilization of individual dysfunction, rather than the facilitation of ongoing growth of individuals and communities. The integration of the ecological perspective in some ways perpetuates this co-optation, but at the same time sets the stage for important new theoretical developments which have already been discovered in allied fields, but hardly in social work as of yet.

One of the most central notions of systems theory is that of equilibrium, homeostasis, or the steady state. Hearn argues that, "After any disturbance, a system tends to reestablish a steady state, and a system can also establish another steady state if and when the disturbing external condition is prolonged." (Hearn, 1979). Life become a succession of steady states, a struggle to constantly maintain one's balance. This assumption that organisms are equilibrium-seeking is fairly widespread, and ignores findings from chaos theory that many complex adaptive systems are far from equilibrium, that they can never exactly repeat themselves. The assumption of homeostasis, I argue, is a misunderstanding of GST, one which in part rests on a lack of knowledge of the dynamics of feedback loops.

Most commentators on GST include a few sentences on feedback loops, circular causal relationships which define the functioning of physical, biological, and social systems. Most present a fairly clear picture of what are called negative feedback loops, which operate something like the proverbial thermostat which constantly brings the target variable--temperature--within acceptable bounds (Hearn, 1979; Compton and Galaway, 1994). To the extent that we see the world as consisting of such "deviating-counteracting" feedback loops, life will appear to be a succession of steady states, punctuated by occasional disturbances. However, commentators too often give short shrift or misreport the opposite type of feedback loop involving positive or deviation-amplifying feedback. For example, Compton and Galaway mistakenly define the concept as suggested by their statement that, "Positive feedback is generally held to indicate that the system is behaving correctly in relation to its goals and that more behavior of the same quality is called for." (1994). Positive feedback, as the term is ordinarily used in systems theory, carries no normative implication; it is not good or bad. It is 'positive' because it is "deviation amplifying." (Hearn, 1979 from Maruyama, 1963). This may be exemplified by a painful matter, such as a psychotic regression ("When it rains, it pours."). Or for some, it may be a happy occasion ("The rich get richer and the poor get poorer"). In either case it represents a process that feeds on itself and breaks out of old bounds, creating either precipitous breakdown or seemingly sudden leaps to higher levels of creativity and functioning. Whereas negative feedback helps us understand stability, positive feedback is a key means for understanding change and growth.

Occasionally included in the rendition of GST concepts is that of tension. Compton and Galaway, for instance, argue that tension is necessary to complex adaptive systems, implying perhaps that they believe that external tension is the primary source of change and growth (1988). While few would argue that tension

and external challenge has not been an important source of biological and social change, the issue is whether it is primary source of such change. Petr, in contrast, argues that there are two basic system perspectives. The first, he suggests, maintains a basic cause-effect, reactive and mechanistic orientation, whereas the second perspective views cause-effect as secondary to the more primary, active, spontaneous, and autonomous nature of systems (Petr, 1988, p. 623). In some respects, this represents the difference between an older mechanistic view of systems, and a biological understanding of systems, one which relies not so much on an older Darwinian understanding of evolution, but which instead sees natural selection as secondary to processes of self-organization and emergence, one which fine-tunes the results of these often sudden phase transitions.

Despite its many limitations, general systems theory, especially since it has been modified by ecological theory, has brought the profession to the 'edge of chaos' in several important ways. Discouragement over discovering a truly integrative framework, has perhaps led to many social workers away from concerning themselves with theory, inciting many to scurry about for the latest and most fashionable and reimbursable techniques, a type of fragmentation and chaos we do not need. But it has also led a few of us to explore the emerging field of chaos theory, more accurately referred to as complex systems theory, as it is in this emerging field that we can see solutions to many of the conceptual blockages to theory development that social work has faced, as well as the development of specific methodologies for researching the kinds of systems we are committed to working with in social work. But perhaps most important, the 'edge of chaos' is regarded by many to refer to those conditions in complex adaptive systems which are maximally conducive to creativity and problem-solving (Packard, 1988).

### **Overview of Chaos Theory**

Chaos theory at its heart is a collection of conceptual, mathematical, and geometrical techniques that allow one to deal with complex systems with are characterized by periodic, nonlinear, dynamic, and transitional elements (Çambel, 1993). In its inception, the theory was developed to deal specifically with systems characterized by the mathematical notion of "chaos". Chaos, in this sense, refers to systems which can be found at an intermediate point in the continuum which ranges from the completely periodic and predictable to the totally random, and in which there is a type of order which never exactly replicates itself. Examples of such systems include weather, healthy EEG patterns, stock market behavior, and many social systems.

As chaos theory has developed the approach has been regularly applied to a range of complex, dynamic, and nonlinear systems which do not technically qualify as representing the narrow mathematical notion of chaos. This broader field has been variously referred to as that of nonequilibrium theory (Loye and Eisler, 1987), self-organization theory (Kaufman, 1995), nonlinear dynamics (Hilborn, 1994), complex systems (Lewin, 1992), or complex adaptive systems, each of which have typically attempted to integrate what is known of the three major classes of processes: deterministic, chaotic, and random (Kincanon & Powell, 1995). While chaotic processes are believed to take place in all major categories of systems--conservative, dissipative, and quantum--most work has focused on the occurrence of chaos in dissipative systems, of which biological and social systems are prime examples (Çambel 1993). It is important to note that while not all complex systems or nonlinear phenomenon are chaotic, it has been hypothesized that all chaotic systems are inherently nonlinear (p. 16).

**Historical Roots.** The idea of chaos can be traced back to ancient Greek and Chinese philosophy, as well as to Hegel's philosophy of history (Loye and Eisler, 1987), but the most important work foreshadowing this field was done by Henri Poincaré, a French mathematician of the late 19<sup>th</sup> Century (Halsz, 1995). Poincaré conducted mathematical studies of the stability and dynamics of the solar system and

discovered that the most important features of the required differential equations were not their solutions in numbers (Galatzer and Levy 1995), but the qualitative properties of their solutions. He discovered the limit cycle, as well as the notion of the equilibrium point (Halsz, 1995). Other predecessors included Kurt Lewin, with his notion of freezing and unfreezing structures (Loye and Eisler, 1987); Rene Thom, the founder of catastrophe theory (Galatzer-Levy, 1995, p. 1093); and most significantly, Edward Lorenz, who in 1962 discovered the existence of chaotic structures, technically referred to as “strange attractors”, in weather patterns (Loye and Eisler, 1987). The field of chaos theory, however, did not develop its identity until the eminent mathematician and biologist, Robert May (1976), pointed out that certain seemingly simple equations may represent very complicated dynamics, popularizing the work of Li and Yorke who were first to introduce the term chaos in their paper: “Period Three Implies Chaos” (1975).

**Key Concepts.** At the heart of chaos theory is the notion that complex systems can often be characterized by fairly simple mathematical equations (Mandel, 1995). Typically an equation is determined which relates the level of a variable at time A and time B. This equation is then used iteratively to calculate the value at time C, D, E and so forth, in each period using the output of the former calculation as the input for the next period’s calculation (Heiby, 1995). By such simple iteration or feedback, it has often been found that fairly simple relationships underlie what appears to be complex or chaotic behavior. In a similar fashion, the complex behavior of flocks of birds or crowds of people can be characterized through the repetitive application of simple decision rules used by each individual: “...global structure emerges from local activity rules, a characteristic of complex systems.” (Lewin, 1992). Chaos theorists have also developed a wide range of graphic devices, such as phase diagrams and fractals, to characterize and explore such systems (see Hilborn, 1994). But the central methodology involves the analysis of time series (Haynes, et al, 1995, p. 17).

Central to chaos theory is the study of *nonlinearity*. In linear relationships there is a proportional relation between cause and effect: cut twice as much from the welfare budget, and twice the number of recipients will be dropped. Much more common in the real world is the nonlinear or curvilinear relationship, which represents the nonproportional relation between cause and effect, and can be exemplified by the adage of the ‘straw which broke the camel’s back’, or the idea of a critical mass or threshold. Although nonlinear relationships are a necessary but not sufficient condition for chaotic systems, they are ubiquitous in both natural and social systems (Kincanon and Powell, 1995). In the author’s own research, he has found that curvilinear relationships typically better characterize the association between many social work inputs, such as number of therapy sessions or rate of homeless shelter coverage, and various measures of satisfaction and outcome, than the conventionally assumed straight line relationship ( , 1997). Despite the obvious importance of such relationships, attention to them is rare among social work researchers.

Just as in general systems theory, the notion of *feedback* is central to chaos theory. Typically the feedback is represented in the process of iteratively characterizing or projecting a time series; the results of previous calculations are the input for succeeding calculations (Blackerby and Fortunato, 1993). Similarly, this feedback process may be either negative or positive, deviation-reducing or deviation-amplifying, or some combination. Such amplification may result from the operation of a single variable, or the combined effects of several. In any case, time series which settle down to a regular linear or periodic pattern are often characterized by negative feedback, whereas those which never settle into a completely predictable pattern, are likely characterized by positive feedback processes (see Arthur, 1990).

One of the most widely cited concepts from chaos theory in the social science literature is that of *sensitivity to initial conditions* (Richards, 1996; Galatzer-Levy, 1995; Krippner, 1994; Heiby, 1995; Robinson, 1993; You, 1993; Mandel, 1995). This notion originates in Lorenz’s discovery concerning the unpredictability of weather patterns (see Lorenz, 1993). Despite his success in mathematically characterizing

convection patterns with three simple differential equations, he found that these equations could not be used to predict the weather beyond a short range because the effects of the smallest discernible errors in the measurement of initial conditions served to become so magnified over time as to nullify any ability to predict. This sensitivity, which is characteristic of all chaotic systems, is the basis of what has been referred to the “butterfly effect” as it has shown that a butterfly flapping its wings in Sumatra can result in a 5 degree centigrade change in temperature in Atlanta, Georgia, eight days later, or a tornado in some other part of the world (Lorenz, 1972; Galatzer-Levy, 1995). Small initial errors and perturbations sometimes endlessly magnify, through positive feedback loops, to create major changes, a phenomenon often observed in the physical sciences. While such sensitivity provides one additional nail in the coffin of mechanical predictability, it does not suggest that the general form or overall pattern of the time series can not be predicted, assuming that chaotic structures (or “strange attractors”) can be identified; only that the specifics of future behavior can never be precisely defined.

There has been much speculation on the significance of sensitivity to initial conditions in the social sciences. Krippner suggests that “chaos theory holds that through amplification of small fluctuations, it can provide natural systems with access to novelty.” (1994). Similarly, Duke aptly points out that “sensitive dependence” leads to the understanding that small things can have major repercussions; that we can not overemphasize large traumatic events.” (1994). A single act of kindness or particularly well-timed intervention on the part of a social worker can have major repercussions, usually beyond his or her ability to appreciate.

Central to chaos theory is the concept of the *attractor*. According to Lewin, most complex systems exhibit what mathematicians call attractors--states or patterns which the system eventually settles into: “The network at some point hits one or a series of states around which it cycles repeatedly.” (1992, p. 20). Until the work of Lorenz, it was presumed that chaotic systems tended toward stable equilibrium (fixed point) or period attractors.(state cycles) (Krippner, 1994). However, beginning with Lorenz it was discovered that some systems, though falling into a familiar pattern, never exactly repeated themselves, and it has been mathematically shown, if they are iterated *ad infinitum*, they will never repeat themselves (Devaney, 1989). Thus, in addition to the traditional fixed point, limit cycles, and torus attractors, there are the “strange attractors”, some examples of which are found in figure 1.

[INSERT FIGURE 1 ABOUT HERE]

An important but less often used concept from complex systems theory is that of *entrainment, slaving, or mode locking*. This refers to the tendency of periodic patterns, when sufficiently replicated, to create a threshold effect which then spreads to other systems (Gleick, 1987, 292-3). This has been observed for hundreds of years in clock shops, when despite an initial asynchronous ticking of the clocks, each clock will tend to fall into unison. Such a phenomenon can be used to understand both the pernicious effects of mental hospitals on their patients, as manifested by institutionalism, as well as the possibilities of positive behavioral change emerging from programs which provide a minimum required threshold of input and support.

Also rarely mentioned in the social sciences, but critical to the science of chaos is the concept of *bifurcation* (see Hilborn, 1994, pp. 140-160 & 599-627). In the physical sciences it has often been found that as a key parameter is increased, key thresholds are reached in which a process splits into two subprocesses or perhaps alternating rhythms. As the parameter is increased further--but to a lesser degree--further splittings occur, and typically after three to five splittings, a chaotic pattern ensues. As such, the study of bifurcations is considered to be the study of paths through which systems develop chaotic patterns. A universal number, one of the most important discoveries in chaos theory, is known as the Feigenbaum Constant (4.6669202...) and has found to govern the successive levels at which bifurcations occur in many natural systems (Çambel,

1993, pp. 121-4). It may be that as levels of such conditions as “expressed emotion” (EE) increases in families with schizophrenic members above certain thresholds, that the psychological and biological processes associated with schizophrenia may undergo key alterations.

One branch of chaos theory has focused on what has become known as *emergence* or *self-organization*. Several eminent biologists have identified what they consider to be the “spontaneous appearance of organized structure throughout biological evolution and social development.” Kaufman argues that self-organization is the “great undiscovered principle of nature” and that it and natural selection the twin engines of the biosphere (Kaufman, 1995). A system is defined as self-organizing “if it acquires a functional, spatial, or temporal structure without specific interference from the outside (Haken, 1988). Processes of self-organization can be observed in such natural systems as the structure of the spiral arms of a galaxy, that of a tornado, or the eddies in fluid flow. (Ehlers, 1992). Similarly, Prigogine and Stenger advanced the notion of “dissipative structures” in which order is formed “for free” out of randomness through such processes as autocatalysis, cross catalysis, and nucleation, in which materials which foster key subprocesses, when certain thresholds are passed, link together to form complete feedback loops, which in turn eventually combine to create higher order adaptive systems (1984).

The application of such principles to social systems has been minimal. An important exception, however, is the work of Stuart Kaufman who applies this perspective to understanding economic growth and development (1995, pp.273-305). To date, principles of self-organization and emergence are one of the few viable alternatives to an exclusive reliance on natural and social selection to understanding social change. Recently, Laszlo has applied these notions to social systems in his attempt to place chaos theory into a broader perspective, proposing a theory which he refers to as the Grand Evolutionary Synthetic Theory (GEST) (1987). He characterizes the dynamics of this transformational process as lying in the interaction of a “ $\beta$  Function” of auto- and cross-catalytic cycles governed by negative feedback, in which systems governance is centralized, and a “ $\gamma$ -Function” of deviation-amplifying positive feedback in which systems governance shifts to the periphery. Social evolution is, thus, seen as the alternation of long epochs of stability governed by negative feedback loops with much shorter crucial periods of revolutionary change, dominated by positive feedback loops (1984). Supplementing the idea of self-organization which mainly takes place in short pivotal periods, is the notion of *co-evolution*, in which various individuals and social entities continually adapt to each other’s adaptive efforts, “tuning themselves to the point of maximum computational ability, maximum fitness, and maximum evolvability.” (Lewin, 1992, p. 62; see also Kaufman, 1995).

In addition to strange attractors, bifurcations, and self-organization, the structure of chaotic and other complex systems are also studied using the concept of *self-similarity*. Besides the principle of sensitivity to initial conditions, this is also one of the most widely used concepts from chaos theory in the social sciences. It refers to the observation that, “Complex systems often involve structures that repeat basic features on several different levels of observation.” (Galatzer-Levy, 1995, p. 1095). Whether a coast line or a snowflake is examined close up or from a distance, certain key features repeat themselves at each level of magnification. In the same way, some psychoanalysts have pointed out that important patterns repeat themselves in the analysis of their patients, whether it be in the micro-process of the therapy interview, the overall process of analysis, or in life-long patterns of their patients (Galatzer-Levy, 1995). Similarly, the popular notion of “parallel process” exemplifies this phenomenon in a different way, as key dynamics of a case may come to be played out in a staffing, and at higher organizational levels. In the same way, inter-organizational dynamics may come to be replicated on the staff and client levels.

One of the techniques that chaos theorists have used to study chaotic processes is through *fractals*. Fractals are typically abstract visual representations of some of the same iterative mathematical calculations

which are used to characterize chaotic processes. A key feature of many fractals is the self-similarity of form which is found sometimes on any possible level of magnification. Yet, usually, the patterns are never exactly replicated (see Levinson, 1994; Devaney, 1987; Çambel, 1995). While fractals have so far had few practical applications other than in the simulation of natural landscapes in computer games, using remarkably brief mathematical algorithms, they represent an important technique for the study of chaotic processes and systems.

Many fractals contain boundary regions between periodic and random areas in which highly intricate chaotic structure can be found. Several authors have focused on such phenomenon in both natural and biological systems, referring to this phenomenon as the *edge of chaos* (Packard, 1988; Waldrop, 1992; Richards, 1996; Lewin, 1992). Lewin for example, argues that:

The edge of chaos is where information gets its foot in the door in the physical world, where it gets the upper hand over energy. ... Being at the transition point between order and chaos not only buys you exquisite control--small input / big change--but it also buys you the possibility that information processing can become an important part of the dynamics of the system." P. 51 (Lewin, 1992)

Others, such as the psychologist Ruth Richards, argue that the ability to function at the edge of chaos is one of the most important conditions for creativity and effective problem solving (1996). Because chaotic processes never repeat themselves, they represent an endless source of novelty. The ability to maintain creative growth in non-equilibrium systems, combining negative and positive feedback, and balancing periodic and chaotic structures 'at the edge of chaos', is no doubt a phenomenon which proponents of the now dated general systems theory are liable to miss without the insights and tools of chaos theory.

### **Applications of Chaos Theory**

Many have argued that chaos theory serves as the most powerful and general paradigm available for the study of complex systems (Çambel, 1993). The most extensive applications of chaos theory have been in the physical and biological sciences (see Hilborn, 1994), somewhat less so in medicine, particularly in neurology and cardiology, and in economics, psychology, and a wide variety of other fields. Coverage of chaos theory in the social work literature, however, is almost nonexistent. When it has been used in fields such as psychology and social work, applications tend to involve only the conceptual or metaphorical use of chaos theory, rather than its mathematical and graphic tools.

In medicine several researchers have used chaos theory in the study of the brain, nervous system, and perceptual apparatus. Garfinkle, et al. (1992) discovered that EEG patterns during normal functioning can be characterized by chaotic structures or attractors, whereas during epileptic seizures, periodic attractors become predominant. Similarly, Pool found that Parkinson's Disease may be caused by a loss of chaotic variability (1989, pp. 606-7). Freeman and his associates investigated perception in animals and found that "chaotic behavior serves as the essential ground state for the neural perceptual apparatus, and that upon recognition of new sensations chaotic electrical brain signals appear to collapse into orderly firing patterns (Freeman, 1991; Skarda & Freeman, 1987). Related areas of research application of chaos theory include sleep neurophysiology (Basar, 1990), neuroendocrinology (Fischer & Smith, 1985), and psychophysics (Westheimer, 1991). In contrast to neurological functioning, in which chaotic patterns appear to be associated with health, in cardiology chaotic patterns have been found to be associated with dangerous heart arrhythmias and fibrillation. Using chaos theory, Garfinkle et al. succeeded in determining key points to administer electrical stimuli to bring the fibrillating heart back to a normal beat (1992, p. 401).

Although applications in psychology appear to be fairly widespread, most of these involve only selected concepts, rather than the methodologies of chaos theory (Grotstein, 1991). For example, Duke uses

the 'butterfly effect' to conclude that, "The sources of specific day-to-day lasting behavior patterns, as well as the sources of problems in functioning, are not limited only to major events in people's lives, but also include relatively small events, which, over time, can result in a significant impact on behavior." (1994, p. 275). While sensitivity to initial conditions, strange attractors, and self-similarity are perhaps the concepts from chaos theory which are most widely used in this field, less attention has been paid to phase states, bifurcations (Haynes, 1995), as well as self-organization and the edge of chaos phenomenon. The field has recently seen the formation of the Society for Chaos Theory in Psychology and the Life Sciences<sup>2</sup>.

Several authors have sought to use chaos theory, in conjunction with general systems theory, as a conceptual framework for psychological assessment (Kossmann, 1993; Blackerby and Fortunato, 1993). Blackerby and Fortunato, in particular, argue that chaos theory "provides achievable frameworks for potential identification, assessment, and adjustment of human behavior patterns." (1993). Similarly, Haynes points out that the use of chaos theory is not only consistent with general systems theory, but that it would strengthen multidimensional assessments, and would be consistent with time sampling, longitudinal, and ideographic approaches to assessment (1995).

Several psychologists have specifically sought to apply chaos theory to problems in human development. Specifically, the concept of the attractor has been used to understand both stability and variability in developing organisms, which are believed to be "neither stereotyped or 'hard wired' nor are they random. Behavior fluctuates, but within limits. That is, organisms tend to show a delimited number of behavior patterns, which within certain boundary conditions, will act like dynamic attractors." (Thelen, 1989, p. 86). Other applications within the field of human development have been reported by Kossmann (1993), Schwalbe (1990), and Blackerby and Fortunato (1993).

Other important applications of chaos theory in psychology have been in the field of psychopathology. Particular attention has been paid to schizophrenia, in particular, to both eye movements (Huberman, 1986) and behavior patterns (Schmid, 1991; Paulus, 1996) on the part of its victims. One study, for instance, aimed to quantify the complexity of behavioral sequences of patients with schizophrenia, compared with normal subjects, using nonlinear dynamical systems theory (Paulus, et al. 1996). The study concluded that patients with schizophrenia exhibit complex patterns of dysregulation, rather than "simple up- or down-regulated predictability of response patterns." (p. 716). Other conditions investigated include schizophreniform disorder (Duke, 1993), anxiety (Bütz, 1993, p. 544), and depression (Heiby, 1995). On the whole, chaos theory has led to the construction of models of illness which take exception to the standard medical model that holds that a healthy body has rather simple rhythms, tending toward homeostasis, in contrast to more complex patterns in illness (Krippner, 1994, citing Pool, 1989).

A number of psychotherapists have used chaos theory to conceptualize processes of psychotherapy and psychoanalysis. Whereas Spuriell (1993) characterizes the therapeutic process as iterative in a similar manner as is used to characterize chaotic processes, Galatzer-Levy uses the notion of self-similarity to describe the tendency for behavioral themes to become replicated on various levels in the psychoanalytic process (1995). Many of the applications in this area tend to be simplistic, revealing a fairly superficial understanding of the concepts of chaos theory. Nonetheless, when psychotherapy is conceptualized in its nonlinear, interactive, and emergent dimensions, a range of useful hypotheses can be generated.

Examples of applications in related fields can be found in decision making and organizational behavior (Michaels, 1989; Smithson, 1997), group process (Lichtenberg & Knox, 1991), as well as the field of education and remedial reading (you, 1993; Doll, 1989; Robinson and Yaden, 1993; Sawada and Caley, 1985, p. 17; Luce, 1995), as well as sociology. An important example of a sociological application is the

work of the urbanologist, Jane Jacobs, who used chaos theory to compare the developmental experience of Manchester and Birmingham, England. She describes how during the industrial revolution, Manchester, deteriorated because it was orderly, indeed regimented, and did not have the flexibility to be competitive. In contrast, Birmingham was quite disorganized with many diverse businesses, and was 'a muddle of oddments' according to Jacobs. However, because of these more complex, chaotic patterns Birmingham was better able to adjust to changing circumstances better than Manchester, and continues to thrive and to have a higher quality of life to this day. (cited in Çambel, 1993).

### **Implications for Social Work**

Both chaos theory and the broader field of complex systems theory represent significant extensions of general systems theory. They enable the practitioner to develop an appreciation for dynamic processes which take into account not only a wider range of nonlinear feedback relationships, but also a plethora of structural patterns, such as strange attractors with their self-similar and self-organizing properties, which were unknown to the founders of systems theory and traditionally discounted as random noise or error. Yet, there is a dearth of published efforts to apply chaos theory in social work. Unlike "systems theory" or "general systems theory", for which there has been over 120 articles between 1977 and 1997 in the social work abstracts, the term "chaos theory" only appears in 2 articles (De Jong, 1995; Parnell and Vanderloot, 1991). In contrast, there have been 103 articles in the psychological abstracts concerned with chaos theory in only the last five years.<sup>3</sup>

Chaos theory brings both good and bad news for social work. On one hand, if one accepts that most social systems probably contain significant chaotic processes, the problem of predicting therapeutic or other interventive outcomes, and thus that of optimization, will remain intractable, as the slightest alterations in initial or intervening conditions can be expected to completely change point-in-time outcomes. However, if we are more interested in predicting the existence of overall trends and processes in our client's lives, then chaos theory clearly serves to facilitate prediction, and thus interventive decision making. Galatzer-Levy elaborates on this point from a psychoanalytic perspective: "We are not so interested in the momentary level of regression of a patient as in his or her capacity to move in and out of regressed states in the course of the analysis. Predicting the form of evolution of a system is thus closer to our clinical interests than the classical position was." (1995; P. 1100). Chaos theorists have identified a wide range of interventions in chaotic processes as well as periodic processes, including the destabilization of an equilibrium by increasing the sensitivity or gain factor in a potentially positive feedback relationship, or conversely, through the introduction of time delays or recovery periods for permitting return to periodic patterns (Ehlers, 1992).

Without substantial improvements in the profession's ability to develop more sophisticated quantitative skills in its practitioners, the application of chaos and complex systems theory is likely to be restricted to the conceptual and hypothetical-deductive level. Actual research on chaotic processes usually requires extensive time series data, and for many processes, an understanding of calculus for their analysis, both of which even most social work doctorates do not have ready access to. However, the use of concepts from chaos theory to describe social phenomenon and to generate hypotheses concerning the dynamics of social processes and points of possible intervention is clearly within the capabilities of most social workers. If social work theorists and researchers succeed in developing better typologies of social and psychological processes using complex systems theory, in the same way that psychopathologists categorize mental illnesses, practitioners will be in an especially strong position to locate strategic points of intervention. If complex systems theory, within which is embedded the more specialized chaos theory, is understood as complementing and building on general systems theory, rather than replacing it, the practitioners will be more likely to develop an integrative view of the interaction of linear and non-linear, recursive (one way) and non-recursive (two-way

feedback), and periodic and chaotic processes which together define most psychological and social behaviors. Much of the excessive rationalism of GST has persisted in complex systems theory, however, an expanding range of applications in such fields psychoanalysis, literature, and religious studies suggests that the minimization of subjective experience is by no means inherent to the approach. In many cases, qualitative research methods are critical means for the exploration of nonlinear, dynamic phenomenon, especially those not directly observable.

If social work is to upgrade its capabilities to intervene in complex systems, it is critical that social work researchers enhance their ability to model the dynamics of these systems and the interventions meant to influence them (see De Jong, 1995). Cross-sectional surveys, one of the predominant methodologies in social work research, will need to be increasingly supplemented with time series data, whether this is collected through observation, self-ratings, or experience sampling methods (ESM).<sup>4</sup> Although statisticians have yet to fully develop methodologies which enable the comprehensive analysis of multivariate times series, ones which involve nonlinear, non-recursive, and non-normal data, considerable progress is being made on several fronts. These include chaos theory, as well as structural equation modeling, multilevel modeling, and the simulations developed by system dynamicists.<sup>5</sup>

It is, however, premature to conclude that chaos theory or complex systems represents a new paradigm for social work, if for no other reason than the sparsity of its use in the social work profession to date, either by practitioners, theoreticians, or researchers. But it is also clear that both the concepts and methodologies of chaos theory promise to significantly extend the profession's ability to understand the increasingly complex systems it is regularly asked to intervene in, moving us beyond the limitations of general systems theory. This especially includes an understanding of natural processes of change, growth, and the self-organizing and emergent properties of these systems which are most readily found at the edge of chaos, a place where social work has perhaps always been.

**Figure 1.** The four major classes of attractors are depicted above, as traditional time series in the top row and as attractor portraits in state space along the bottom row. The two figures in column A illustrate the fixed point attractor which converges to an unchanging condition. Column B illustrates the time series which repeats itself periodically, representing a limit cycle in state space. Column C repeats itself in a more complicated rhythm, creating a torus in state space. Column D represents a chaotic pattern characterized by a non-repeating strange attractor (Lorenz). [Permission for reprinting being sought from Irving R. Epstein].

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## NOTES

1. The last line in brackets has in popular usage come to be added to this quotation, but can not be attributed to Benjamin Franklin (see Bartlette's Quotations), despite the fact it more dramatically reflects the notion in chaos theory referred to as "sensitivity to initial conditions" or the "butterfly effect" (see Overview of Chaos Theory).
2. This organization maintains the following web site:  
<http://www.vanderbilt.edu/AnS/psychology/cogsci/chaos/cspls.html>
3. A similar search produced 13 articles with the word "chaos", without the word "theory", 11 of which used it in a generic manner, with no reference to "chaos theory". There were no articles in the social work database which referred to nonequilibrium theory, complex system theory, complex adaptive systems, or self organization.
4. Although the requirements for data points in such time series are daunting, reported to be between 800 and 30,000 (Devaney, 1987), there have been significant findings with considerably fewer time points. Using only four time periods, but multiple cases, -- provided strong evidence for the existence of a strange attractor which governed the developmental processes in the world's major cities. This study illustrates that, when it is assumed that various subjects are at different stages of a developmental process, multiple observations can partially substitute for the technical requirement for numerous timed data points.
5. For "Road Maps", newsletters, and various papers describing applications of "system dynamics" in K-12 education, contact:  
Professor Jay Forrester, Systems Dynamics in Education Project, System Dynamics Group, Sloan School of Management,  
Massachusetts Institute of Technology, Cambridge, MA.