An Introduction to Chaos Theory for Psychodramatists

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ABSTRACT. Individuals and groups are dynamic systems that generate patterns of behavior, thoughts, feelings, and interactions. Chaos Theory (ChT), based on a mathematical approach to nonlinear, nonindependent modeling, addresses these patterns. ChT has important insights to offer psychodramatists, both conceptually and practically. Psychodramatists need a basic, working knowledge of ChT and its impact and implications. In this article, the author presents a mathematical and conceptual overview of ChT and briefly relates it to the basic subsystems of Morenean thought. These insights are bases for future practice, theory, research, and training implications to be explored in other manuscripts.

Keywords: chaos theory, dynamic systems, patterns, psychodrama

PEOPLE, INDIVIDUALS, AND GROUPS ARE DYNAMIC SYSTEMS, and their actions and their interactions generate patterns. Chaos Theory (ChT) concerns the patterns generated by dynamic systems. It is based on a mathematical approach to the nonlinear, nonindependent modeling of patterns of behavior. ChT is not, per se, a philosophical system or paradigm. In fact, it is as nonbiased as any mathematical approach can be, which is not to say that it is without its assumptions. ChT has important insights to offer psychodramatists, and more important, implications for the conduct of social science as a whole. The Vatican is even interested in the ramifications of ChT for religious doctrine (Russell, Murphy, & Peacocke, 1995).

Psychodramatists, professional psychologists, other social and physical scientists, and even laypeople need a basic, working knowledge of ChT and its implications because that background is essential to understanding and functioning effectively in the world and to helping people. The effects of the theory are so far-reaching that they go to the core of how we approach science.

Many, if not all, concepts that constitute ChT are not new and have existed for some time in one form or another. In fact, one recognizes them in sayings and such adages as "for want of a nail the shoe was lost, . . ." Their juxtaposition and connection, the development of concise, scientific language to define their related constructs, and, most important, the application of concrete, systematic, logical mathematical procedures to substantiate them lend them new validity, credibility, and clout.

Mathematical approaches to modeling as applied in other disciplines focus on the modeling of patterns of behavior, with the subsequent goal of predicting, if not controlling, them. That description fits much of what we, as psychodramatists, do rather well. However, we are not limited to patterns of behavior. We also deal with patterns of feelings, thoughts, and interpersonal interactions. Those phenomena are more challenging to address because the data available to do so are usually, if not always, difficult to produce and of a less than optimal, solid, ratio-scale type. That leads to questioning whether ChT does and can apply, but that argument is grounded more in logic than in empirical evidence, at least for those latter three areas.

A Personal Vision Shared

In this article, I share my vision of the importance of ChT to psychodrama in particular and to the social sciences in general. Although this account may seem to be a translation of psychodrama concepts into ChT terms, I believe its relevance goes far beyond that kind of impact. ChT conveys the underlying process and characteristics of dynamic systems—perhaps even as universals—that unify phenomena at different levels from social to biological to chemical to physical. That understanding helps explain what the psychodrama process does and how it does it. For example, noting that self-organization occurs during the process of integration allows a director to step back to observe the interaction of components (roles), knowing that some order will emerge, although not necessarily or likely what might have been anticipated or planned. The same applies to life in general.

Even if the outcome is only a type of translation, the process is worthwhile, as those who struggle with comparing and integrating different theoretical perspectives learn. Psychodrama is role-playing behavior. The process, especially of translation, suggests that concepts, terms, and words are not isomorphic. The process itself demands an extension of "making meaning" (Remer, 2001a). Beyond the translation, ChT, being mathematical, not only presents another mode of thinking but also offers approaches to exploration not available at present to psychodramatists committed to supporting the usefulness of Morenean conceptualization—nonlinear mathematical modeling. Is that fit demonstrable, especially empirically? Honestly, I do not know. But thinking "chaotically" has had such a significant impact on my approach to science, my understanding and use of psychodramatic techniques, and my personal worldview, that I hope to convey and share those effects and get help in developing them further.

To start, we need to look at what ChT is mathematically. We also need to look at the assumptions about patterns of behavior, thoughts, feelings, and interactions on which our science is founded. Then we must look at the match to psychodrama.

Some Basic Assumptions of Science

Although numerous assumptions undergird what we call science (from the logical positivist perspective), I focus on seven: (a) predictability, (b) cause–effect, (c) linearity, (d) exclusivity, (e) simplicity, (f) reductionism, and (g) objectivity. Others, although important, are not germane because they either are variations—bifurcations—of these seven or are shared by ChT and not relevant to understanding its ramifications.

Probably the most important basic assumption we make as social scientists is that the phenomena we study—the patterns of behavior, thoughts, feelings, and interactions generated by human beings—are not entirely random, if random at all. They are to some degree describable and predictable—theoretically entirely so. If we do not posit this assumption, we have nothing to study. But what "nonrandom" means and implies is a bone of contention, both practically and theoretically, and even philosophically.

In particular, the issue of predictability and randomness is essential to the implications of ChT for social science because predictability is seen differently through the ChT lens. The goal of social science, as of all science as defined at present, is the discovery and application of universal laws pertaining to our foci, the patterns we address. I say "at present" because most, if not all, social science approaches assume cause and effect relationships, based on the Logical Positivist paradigm. The system producing the phenomena is deterministic. Randomness is viewed as an aberration, many times to do more with measurement than reality, which clouds the path to the establishment of the universal laws.

The view applied in science is linear, in large part because of the cause–effect assumption. The majority of research is analyzed assuming both linearity and independence of observations; even more to the point, things that happen later in time or at the same time do not cause things that precede them or occur simultaneously. ChT, as opposed to linear modeling on which most, if not all, social science is based, has a great deal to say about the efficacy and applicability of our chosen approach.

The logic applied to the study of social science is that of exclusivity—competing explanations being judged against each other. Either one or the other is supported (i.e., an either/or situation). Because they are competing, both cannot be tenable in a given situation. If laws are to be universal, the inconsistencies and contradictions inherent in both being possible—a "both/and" perspective—must be resolved.

"Occam's Razor" is also assumed to apply. Simpler explanations are held tenable when compared with more complex ones, given equal or near equal support.

A reductionistic approach relates both to linearity and simplicity. The assumption is that a phenomenon can be studied, understood, predicted, and controlled by breaking it down, focusing on the constituent parts, and reassembling and summing the resultant information.

A final assumption is objectivity. Phenomena can be viewed dispassionately, without bias. A distance exists between the observer and the object observed, the subject. That removed stance provides for not only a clear view but also an uninfluenced one, meaning that the viewing is impartial and does not change the phenomenon observed. These assumptions then are the structure from which and in which we are trained culturally from an early age. As social scientists and psychodrama practitioners, we have been taught to rely on them, but how tenable are they? If not tenable, what others do we follow? And what consequences befall us if we entertain those others?

The Mathematical Basis of ChT

To understand the essence of ChT, some familiarity with and understanding of mathematics is required. A brief introduction is first, and then I provide the essential constructs of ChT. Then we can make the application to social science, specifically psychodrama.

The equation or model, $x_{n+1} = k\,x_n\,(1 - x_n)$, is called a logistical map. It is a nonlinear, second-order difference equation. Although seemingly simple enough, its behavior (i.e., the patterns it generates) illustrates the essential characteristics of a chaotic, dynamic system. This simple quadratic equation is often used to explain the meaning of chaos in scientific presentations because of its simplicity relative to other more generalizable, multidimensional, or nondiscrete examples. It serves the same purpose here.

The usual situations to which the logistical map is applied are in the physical and biological sciences (e.g., moth populations [Wildman & Russell, 1995], hunter/prey simulations), seem cyclical but are actually more complex. Although a practical example of the application of the logistic map to social science would help, it is not possible to offer one that is readily supportable by empirical data. The interaction patterns in therapy, or any dialogue situation, have a similar kind of cyclical ebb and flow. However, other than counting words generated, which is certainly a possibility, much data of real interest are not solid. Later, however, I argue, on a logical basis, that many phenomena of relevance to social scientists are chaotic and could benefit from the application of nonlinear, nonindependent modeling akin to the logistical map. First, however, we need to consider its mathematical underpinning to grasp the essence of ChT.

To start, I present an explanation of equation symbols. The symbols x_{n+1} represent the observation of the state of the system at time n+1, the successive time after observing the state of the system at time x_n and at time n. Thus, the system is iterative or recursive, its current state depending on the previous state. It is second order, meaning that its state depends only on the previous one. For example, if one has the fifth time point and wants the sixth, one obtains it by entering the fifth time point in the equation: $x_6 = k\, x_5\, (1 - x_5)$. Similarly, if one wants the 10th value in the sequence, one enters the 9th to get $x_{10} = k\, x_9\, (1 - x_9)$.

The logistical map behaves differently, depending on the values of the constant k, called the tuning constant or sensitivity parameter. If $0 < k \leq 1$ (i.e., the sequence of values generated monotonically) decreases, eventually going to 0, extinction results, regardless of the initial value of x_n. If $1 < k \leq 3$, the sequence increases, converging to a single periodic point and limits value to greater than zero (> 0), which is again not dependent on the initial x_n. Both conditions lead to fixed-point solutions, ones that, once reached, do not change under further iteration. For values $3.0 < k < k_{crit}$, which equals approximately 3.57, the sequence fluctuates bifurcating with multiple attracting periodic points, the number of which depends on the value of k with some minor dependence on the initial x_n. When $k_{crit} \leq k \leq 4$ patterns are chaotic, with bifurcation regions containing infinitely many bifurcation cascades, what one usually sees in pictures of chaos, and maximal dependence on initial conditions.

Finally, for $k > 4$, a particularly complex type of chaos occurs. Wildman and Russell (1995) describe the pattern of chaotic behavior in this region and its implications as follows:

> [This region] is particularly complex and can only be described in technical terms (p. 69). . . . Early in the investigation of chaos, it was discovered that the constant breaking up of chaotic dynamics by other sorts of dynamics is a quirk of the *one-dimensional* [emphasis added] case. In higher dimensions (even in the complex plane, in fact) chaos frequently occurs in entire regions and for intervals of "tuning" constants. The virtue of chaos in higher dimensions is that it is more conducive to research using mathematical modeling. . . . Attractors could never be found for chaos in natural systems modeled with one-dimensional maps. . . . The stability of chaos in higher dimensional systems is the key to this type of analysis. (pp. 70–71)

Implicit in that statement is the notion that much more is involved in understanding ChT more fully, both mathematically and otherwise. These further excursus, as Wildman and Russell label them, require definitions of such terms as forward and backward orbits and discussions about mappings of

Cantor sets onto the unit interval, Lebegues measures, and other mathematica. As noted earlier, these fine points—remember the Wildman and Russell exposition—are brief and relatively noncomplicated but beyond the scope of this article. The points do suggest, however, two other important aspects of mathematical chaos that are useful to understand.

The first is "banding," the tendency for bifurcations to cluster more frequently in certain areas than in others. Banding allows the rather accurate identification of these regions. The bandings occur because the mapping of values is contracting, focusing more values in these areas than in others. The second point relates to the contracting. Each bifurcation sequence resembles the others in shape or pattern but on a smaller scale. This "scaling factor," called the Feigenbaum constant, appears not only in the mathematics but also in naturally occurring phenomena. "It appears, therefore, that this number is more than an important mathematical constant. It also seems to be a kind of natural constant; the sense in which this is so is a pressing question for many scientists" (Wildman & Russell, 1995, p. 62).

But what exactly does a pattern being chaotic mean? Wildman and Russell (1985) explain as follows:

> There is as yet no generally accepted definition covering all instances of what mathematicians would like to call chaos. . . . However three properties are jointly sufficient to characterize chaos. These properties—mixing, density or periodic points, and sensitivity—are defined as follows. . . . *Mixing* a property characterizing the *disorderliness* of the dynamic system . . . [like] a pinch of spices will spread throughout a lump of dough if the stretch-and-fold operation of kneading is executed properly. . . . *Density of periodic points* a property characterizing the *orderliness* of a dynamic system [like] the way sour cream curdles in hot coffee: the cream moves in all directions throughout the coffee cup, which are like densely distributed repelling periodic points, in order to clump at certain other points, which are akin to points in a chaotic attractor. . . . *Sensitive dependence on initial conditions,* a property characterizing the *topological entropy* of the dynamic system . . . which describes the way an intricately connected system allows tiny influences to have large effects. (p. 73)

Chaotic systems are both predictable and unpredictable. Because we have a formula into which we can enter values, in theory, we can easily calculate any value desired. So, from that perspective, chaotic sequences are completely determined; however, the values entered for x_0 and k, in most cases cannot be precisely specified. Thus, some kind of rounding errors occur. In chaotic regions, eventually the values generated are unpredictable. Thus, as Wildman and Russell (1995) term them, *eventual unpredictability* entails *temporary predictability*—even to the point of being able to know when a prediction will likely fail, based on the precision of the initial values.

The story of how Lorenz (1993) rediscovered ChT is informative in a number of ways. He was trying to simulate weather dynamics. In running his simulation program on his computer a second time to check results he had from a first run—a process that took thousands of iterations to generate the phase space at which he wanted to look—he was interrupted. When he went back to restart his computer, instead of starting over, he entered the last data point he had on his printout into his program. Instead of getting the same results from the previous run, as he had up to the interruption, he got extremely different values. He figured out that the difference was the result of the rounding error—the differences in the 3rd or 4th or 20th decimal place—between the computer-stored values and those that he had on the printout. He had not been able to enter the values that the computer would have used, had it continued to run rather than being interrupted, because he did not have those exact values, only very close approximations. Those very slight differences had severe effects.

That chaos in modeling has to do with rounding error provides further insight into the mathematical inconsistencies between what social scientists do at present and the pattern production of dynamic systems. Rounding errors—little slippages that cannot be foreseen or controlled—are like many influences in dynamic systems and subsystems. If we take a linear perspective, we develop a model using the mean or some variation, in which the "errors" and other fluctuations are eliminated from consideration through averaging effects. However, the situation in most instances is not linear. What happens with nonlinear models, such as the logistical map, is that more and more of those "little differences" accumulate. We cannot see them, let alone foresee them. And, if we could, we could not control for them because their influence is unpredictable, likely one way as much as another. This circumstance makes linear modeling a poor approach. More accurate modeling (i.e., simulation) is better but harder to do.

Chaos is highly sensitive, disorderly orderliness, and that statement or definition leads to how one talks about chaos and its implications.

The Foundation: A Brief Overview of ChT

ChT is about patterns, and about how they develop and change. In the case of psychodrama and the rest of social science, the patterns of interest are usually those of human thoughts, feelings, behaviors, and interactions. The phenomena for which ChT has implications and the manner with which they are dealt are not entirely unique to ChT (e. g., the concept of phase spaces). However, the "philosophical" perspective that ChT and other related or similar mathematical findings suggest is at times at odds with the seven assumptions of social science mentioned previously. I address the 10 most basic constructs: (a) phase space, (b) strange attractors and their basins of attraction, (c) fractals, (d) self-affinity or self-similarity, (e) bifurcation and bifurcation cascade, (f) unpredictability, (g) recursivity, (h) equilibrium, (i) resonance, and (j) self-organization. For more detailed explanations, refer to some of the articles and books listed in the references (e.g., Briggs & Peat, 1989; Butz, 1993, 1997; Butz, Chamberlain, & McCown, 1997; Crutchfield, Farmer, Packard, & Shaw, 1995; Gleick, 1987; Goerner, 1994; Prigogine, 1997; Remer, 2002a; Wildman & Russell, 1995).

For those who are conversant with ChT or its variations and related theories, the literature related to ChT is burgeoning—in physics, biology, ecology, and family systems. I do not discuss all the constructs, concepts, and terms from the myriad valuable expositions and include only those that help me make sense of and use ChT and with which I am familiar. For example, I do not include synchronicity (Strogatz, 2003). I hope that this account will provide an adequate basis and attract others to contribute their perspectives on, enrich our understanding of, and increase the usefulness of ChT.

Phase Space

The *phase space* is the conceptualization, often pictorial or geometric, of the possible states a system might take. Designating the variables that constitute it, usually holding a number of variables constant to simplify the "picture," produces projections or mappings of the phase space or some embedded phase space. By specifying different values of the variables, a mapping of the phase space (i.e., the pattern produced) is obtained. In a sense, though not in the same way mentioned earlier, phase spaces are reductionistic, but necessarily so, because all of reality cannot be considered or modeled at once. More important, the concept conveys that, at best, we see only a portion of "reality" at one time—that part on which we choose to focus. Different theoretical perspectives define different phase spaces or different maps of aspects of reality. No knowledge of the entirety of reality is possible, because Goedel's Theorem states that all that can be known about a system cannot be known from within it. Psychodramatically, a scene can be considered a phase space.

Strange Attractors and Basins of Attraction

Strange attractors are focal points for many, and the most challenging patterns are generated by dynamic, chaotic systems. They are collections or sets of attracting and repelling points making up and generating patterns. Their basins of attraction are the areas containing those patterns within their boundaries. Other types of attractors—point, cyclical, torus—can also occur and can be modeled using ChT mathematics.

Strange attractors and their basins are similar to homeostatic points in General Systems Theory. An example of a strange attractor and its basin is an open bathtub drain when the water is being run fast enough to fill the tub.

Should an object such as a Ping-Pong ball, which is buoyant but too big to be sucked down a drain, be dropped in the tub, it will continue to circulate in a quasi-predictable manner, mapping a phase space. The pattern is predictable in the sense that the ball cannot escape the tub and so its general location is well established (at least until the tub is filled to overflowing); the pattern is *quasi* in the sense that how near to or how far from the drain hole (the attractor) it will be at any time cannot be readily foreseen, particularly for far future times. Strange attractors and basins of attraction, capture the actuality—the consistencies and vagaries of related human patterns. The protagonist, and other auxiliaries for that matter, function as strange attractors.

Fractal Boundaries and Dimensions

Fractal boundaries, or simply fractals, are mathematical representations of the irregular "lines" of demarcation between separate units. Fractal-ness, as I term it, indicates diversity, difference, and complexity of patterns. Fractals and their measure, dimensions, can convey in a systematic, and possibly quantitative, way that reality is rarely as clear and clean-cut as we picture it. Unlike the dimensionalities with which we usually deal, fractals can have fractional dimensions. Shorelines are good examples. From a far distance (e.g., outer space), shorelines appear as continuous, curved lines constituted of long, relatively smooth segments. Walking the shoreline gives one a different impression, as does examining it under a magnifying glass. At each level, what becomes apparent is that all the seemingly long, smooth segments are actually made up of many shorter convoluted pieces. The word "fractal" can convey the concept of convolutions within convolutions as the scale of measurement changes. The measurement of the overall length of the shoreline varies, depending on the accuracy and applicability of the measuring instrument. A yardstick and a micrometer often produce grossly disparate outcomes because measuring the distance around the indentation of every rock and pebble is not done accurately, if doing so is even possible, with a yardstick. Fractals convey two very important concepts. First, what one sees depends largely on one's perspective (see Remer, 1983). Second, accuracy of measurement often depends on the definition of the process—even though results may be internally consistently employing the same method of assessment, they can vary greatly, even by an order of magnitude, using different approaches. Fractals can help capture the fuzziness, the gray areas, and the complexities that are often attendant on human patterns. In doing so, they also emphasize the impossibility of separate systems ever meshing perfectly. Although these types of observations may be made from other perspectives, they are more often seen as nuisances to be overcome. They are, however, central to ChT (see Lorenz, 1993). In psychodrama, the interactions between roles are fractal in nature.

Self-affinity and Self-similarity

Self-similarity and self-affinity, the more general and inclusive term, are constructs that can denote the tendency for iterative, recursive processes and other phenomena to evidence recurring patterns. The constructs of self-similarity and self-affinity capture the sense that motifs seem to be part of nature. Patterns tend to repeat themselves, although not exactly and not perfectly but still enough to be recognizable even on different scales. Similarities, not only of boundaries but also of patterns in general, have proved fascinating, valuable, and enlightening (Hofstadter, 1979). Parenting, both on a reproductive and behavioral level, offers a good example. We tend to resemble our parents genetically, physically, and behaviorally. Nonetheless, in every situation, as many points of nonsimilarity as points of similarity can be found. Behavior patterns tend to repeat themselves, although not exactly. Over time, situations, generations, and so forth, consistencies can be found, as can inconsistencies and fractal-ness—all qualities that are central to ChT. Self-affinity also applies to spontaneous actions.

Bifurcation and Bifurcation Cascade

Bifurcation means splitting in two. When a process or pattern bifurcates, complexity is added to the pattern produced by a system, which means possibly producing or altering strange attractors and their patterns. Bifurcation cascade is when bifurcations happen at such a rate that no discernable patterns seem evident. After a period of time, many natural processes tend to bifurcate as they change. Then, after another period of stability, another bifurcation takes place. As long as the bifurcations stay within limits or happen after long enough intervals so the system's resources can accommodate the new conditions, stability can be maintained (evolution). If either of these conditions is violated, bifurcation cascade may occur (revolution or chaos). The system can go out of control (i.e., become chaotic). Although such a state may seem catastrophic, it need not be. At that crisis point (critical moment or critical point), the system must reorganize into a different, though perhaps very similar, pattern—essentially creating a new strange attractor pattern. Thus, these "confused" states can serve as opportunities for creative, functional change. (Complexity theorists suggest that this state at the edge of chaos is optimal for change. However, given the "butterfly effect," the theory that a butterfly beating its wings in China might cause a hurricane in the Bahamas, how predictably "skating the edge of chaos" is possible seems paradoxical.) Organizational growth can serve as a good example. If the tasks demanded of an organization exceed the capacity of it to adjust, overload (bifurcation cascade) leads to the system becoming chaotic (Pascale, Millemann, & Gioja, 2000). Possible solutions to restabilize the system are different forms of reorganization—new units established to handle new tasks, shifting of tasks to different units within the organization, or farming tasks out to other organizations and in effect producing a metaorganization. Bifurcation and bifurcation cascade encompass some of the notions that General Systems Theory addresses through positive and negative feedback loops (movement to or from homeostasis). Conceptualizing these processes in discrete stages, however, provides a somewhat better grasp of the contributing factors and their interaction (i.e., how a new strange attractor might be the result of a system severely disorganized by the interplay of numerous conflicting forces). This conceptualization also indicates that change need not occur linearly, but rather, can be discontinuous, (i.e., a "quantum leap;" Pascale et al.). Every reenactment is a bifurcation of a previous one.

Unpredictability

Unpredictability is the inability to state with certainty the next state or, for that matter, the previous state, of a system, given knowledge of its present state. A somewhat commonly known aspect of ChT unpredictability has been called "the butterfly effect" (Gleick, 1987; Lorenz, 1993). Small differences in the initial conditions (sensitivity to initial conditions) of a process can produce large differences in outcomes. Conversely, large initial differences can have very little impact because of damping or averaging effects. This second aspect subsumes the concepts of equi-potentiality and equi-finality from General Systems Theory. Other types of unpredictability, consistent with a ChT perspective—the senses conveyed by Heisenberg's Uncertainty Principle (Price & Chissick, 1997) or Bell's Theorem (Kafatos, 1989), Goedel's Theorem (Penrose, 1989, 1994), and the Quantum Mechanics of Schroedinger's Cat (Marshall & Zohar, 1997)—indicate that everything about a system cannot be known to absolute certainty (the construct of phase space) and that any attempt to assess a situation will affect it. I mention these aspects of unpredictability, what I call quasipredictability, because they further affect and reinforce the importance of the ChT perspective. Where ChT unpredictability goes beyond these ideas and can differ drastically is in conveying the humbling, daunting, and realistic perspective of how little control or predictability we actually have, methods and attempts at mathematical modeling are to the contrary. Changing the seating pattern to influence the sociometry of a group is evidence of unpredictability.

Recursivity

Recursivity is self-reflexiveness and self-reflectiveness, which involves feeding information from one's patterns back into the process of producing them. In mathematical language, it is nonlinearity and nonindependence. For an illustration, see the human dynamic system diagram in Figure 1.

Recall the equation for the logistical map, $x_{n+1} = k\,x_n(1 - x_n)$, and the accompanying discussion. This means that when one keeps feeding information about a pattern back into the process of producing it, little differences can tend to become magnified and can blow up to be big differences. Thus, this characteristic of chaotic systems can produce the butterfly effect or a bifurcation cascade, which gives one the sense of being overwhelmed by the chaos one encounters. The same characteristic, however, can lead one to self-correction under the right conditions, which is what one learns from the "tuning constant."

Equilibrium

Equilibrium is the tendency of a system, or its inertia, not to change its patterns but to stay near or return to points of attraction (homeostasis). Patterns change significantly and most unpredictably in systems that are far from equilibrium or chaotic. Those are systems whose sensitivity (tuning constant) has exceeded a threshold of stability. The tuning constant is key. It determines the sensitivity of a dynamic system to the impact of numerous external and internal influences that are buffeting it at all times. In other words, the tuning constant determines whether and how one's patterns change.

Because of recursivity, change depends on the tuning constant, k. What determines k? If by "determine," one means dictate or control, the answer cannot be found, because the sensitivity of the system is too complicated to predict or control. If one means describe (i.e., know what k is at a particular point in time, for a particular phase space), then some enlightenment is possible.

For example, the limbic system is designed to trigger a chaotic reaction producing fight or flight responses. Those responses are noncortical, based on intuitive pattern recognition. In a general sense, one can, and already does, know what influences might sensitize the system, but still one does not know completely because individual, across-time, and situation variations occur. Is triggering a system the same as control? It is, but only to a point and in a very general sense. One may be able to start something, but can one stop it or direct it? Is triggering the same as increasing k?

With k in a certain range, one has the equivalent of a negative feedback loop, in which any influence is dampened and eventually disregarded. If k is

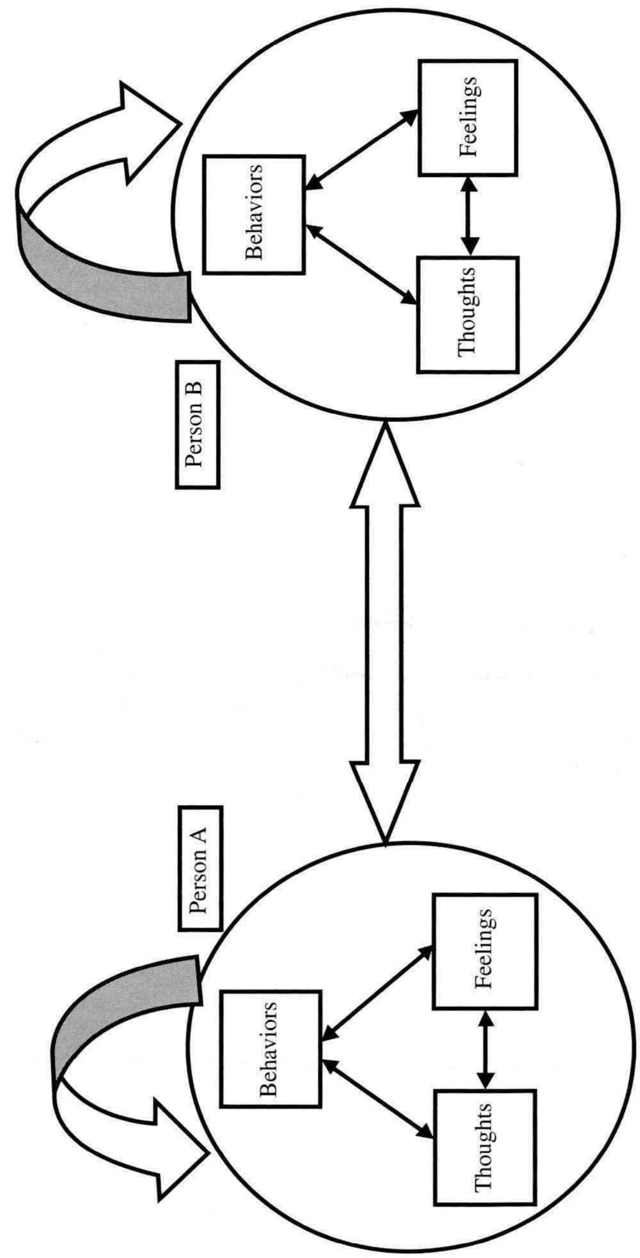

FIGURE 1. Human dynamic system.

increased beyond the critical value, a positive feedback loop is produced, engaging one in rampant and rapid pattern expansion. In the former situation, change is impossible; in the latter, it is inescapable. If one desires change, even seemingly orderly change, one must accept chaos, or at least the potential for chaos. A small band does exist in which bifurcation occurs in a more or less orderly manner, although whether the values to which the system bifurcates are predictable is moot. What may make the change seem orderly is that the attendant chaos is not consciously disconcerting. However, chaos is present. If one desires drastic, significant change, then the system is required to be sensitive, open, and even primed. Those quantum leaps require conscious tolerance of chaos and possibly initiation of it. Some strategies are available for doing the triggering and tolerating, but they do not always work exactly as one likes.

Can k be influenced enough to produce the desired result? The Complexity theorists believe so; I think not. The "edge of chaos" strategy is exactly the wrong one for two reasons: (a) it cannot be done because one does not have that degree of predictability or control, and (b) it does not produce change predictably, if at all. The Strategic theorists have a much more workable approach and capitalize on crisis or chaos when it is occurring to influence change in patterns. They attempt to use sensitivity when it is present and when they recognize that k is large enough.

What this situation amounts to is the recognition that the change in any pattern has more to do with the system being sensitive and ready to change, than with anything else. Moreover, there are the times when changes in patterns are foisted on people by a shift in the patterns of the circumstances that make up a larger system in which the people are imbedded. For example, a psychodramatist's use of the mirror technique relies on its recursivity to have an impact on the client.

Resonance

Resonance occurs when two or more separate entities find their patterns in synch and that synchronicity reappears or continues over time and changes. In other words, there is a type of "connection," at least from time to time and from situation to situation, between or among components of systems that otherwise are distinct.

From a ChT perspective, resonance is important because it engenders the fluctuations in the patterns produced by dynamic, chaotic systems. What is important to grasp and remember is that resonance is **not** the same as cause or influence. It is like a violin's strings that produce resonance because some movement by one string at the right frequency produces a resonance in other strings and a common vibration. As other instances of resonance, consider that some women who know each other well and spend time together frequently have their menstrual cycles in synch, certain subatomic particles shift their spins in relation to each other over vast distances, termites suddenly organize their actions to swarm, or a chemical can change color from red to blue and back without any color mixing—producing a purple hue—or seeming transition.

Explaining the exact working of resonance, not to be confused with its effects, would be useful, but more than offering examples seems difficult, if not impossible. As Prigogine (1997), a noted Nobel laureate in physics, observes, the constituents of dynamic systems possess this resonant quality, and certainly dynamic, human systems possess it. Resonance produces other interesting patterns of phenomena. In such chaotic systems resonance may well be what makes the chaos (the ability to change) and self-organization (the ability to redevelop a coherent pattern) possible.

What does resonance mean to human patterns? It can mean panic, riots, or mob mentality; it can mean apathy or inertia; it can mean serenity, empathy, or community; it can mean mirth, merriment, and exhilaration. Psychodramatic tele depends on resonance.

Self-organization

Self-organization is the inherent tendency for systems in a chaotic state to form a new coherent pattern, which is sometimes termed an emergent pattern. An important characteristic of chaotic systems is their innate ability to reorganize based only on the interactions of their components. Self-organization establishes new patterns; particularly after chaos has been reached, accommodating the new demands on the system. An organization that has undergone bifurcation cascade evidences this attribute. How the self-organization manifests itself, however, usually is not possible to predict exactly. Catharsis of integration is evidence of the self-organizing properties of psychodrama.

What ChT Says About the Tenets of Present (Social) Science

Specifically, ChT differs in its views from the assumptions on which social science is based in at least seven ways, corresponding to the seven assumptions outlined in Table 1. The concepts of phase space and unpredictability of the Heisenberg type contradict objectivity. One chooses the concept on which to focus, and such focusing does not leave the phenomenon unaffected. How influenced and changed one might become is unpredictable.

Reducing a phenomenon to constituent parts is neither desirable nor functional. By doing that, one loses the ability to study the nonlinear, nonindependent interactions of the system as a whole. One also may miss the essen-

TABLE 1. Attributes of Chaos Theory (ChT)

ChT attribute	Contrast (belief in . . . vs. in . . .)
Reciprocally influential	Ability to attribute causation vs. Mutual influence
Dynamic	Enduring explanation vs. Changing perspectives
Inclusive (both/and)	Competing explanation vs. Inclusion of possible alternatives
Possible	Ruling out by stringent criteria vs. Entertaining or combining alternatives
Nonlinear	Linear flow of action vs. Nonpredictable pattern flow
Subjective	Separation of observer and object vs. Influence of observer or perspective on observation
	Objective truth vs. Intersubjective consensus
Organismic	Humans as machines vs. Humans as adaptive organisms
Holistic	Examination of components vs. Examination of an entire entity
Open	Admissibility only of objective information vs. Inclusion and consideration of all types of information
Present-oriented	Control and prediction vs. Description and acceptance of limitations on predictability and influence
Complex	Ability to reduce explanation to universals vs. Changing and adapting to circumstances
Interactive (synergistic)	Whole equals the sum of the parts vs. Whole can be different from or greater than the sum of the parts
Cooperative/harmonious	Controlling and determining outcomes vs. Influencing and adapting as required
Irreversible	Ability to fix and return to previous states vs. Change being impossible to erase
Deterministic (irreversible)	Ability to choose or reverse outcomes vs. Theoretically able to but practically not able to
Balanced (adequacy-oriented)	Ability to find a truth vs. Acceptance of an adequate explanation for moment

tial elements of complex interactions, which are stabilizing. The whole is most definitely not the sum of the parts. Moreover, simplicity (e.g., the one-dimensional case) may not be a virtue.

Strange attractor patterns and their characteristic inclusion of self-affinity and fractal-ness strongly suggest that phenomena are rarely, if ever, either-or propositions. One may be able to define the basin of attraction at one level, but that does not necessarily mean that the pattern is similar enough at another level to allow generalizing. Sometimes a seemingly same stimulus will engender a dissimilar response. One must entertain the possibility of seemingly contradictory ideas being functional and consistent with different aspects of the pattern. Thus, attention to both the nomothetic and the idiographic are balanced (e.g., using such constructs as self-affinity and fractalness). The combination provides an impetus to look not only for consistencies but also for the subtle and not-so-subtle variations.

Linearity is the exception, not the rule. Change can happen both smoothly and disjunctively, by way of bifurcation. Once a change has occurred, it cannot be undone, because the effect stays in the pattern, although it is not necessarily easily recognizable. Cause and effect are at best short-term, if such can be inferred at all, given the recursive and iterative nature of interactions. Moreover, where and how one chooses to enter the system influences the drawing of all inferences.

First, last, and foremost, the ChT view of control and predictability is much more consonant with the view met in reality. Because of the complexity of the chaotic dynamic system's behavior, the interaction and mutuality of the effect of variables on control and predictability are viewed as limited and ephemeral (e.g., Brack, Brack, & Zucker, 1995).

More and more often, change, as exemplified by chaos, has been shown to be the normal, healthy state of a system, more so than a stable, inflexible, nonadaptive status (Butz et al., 1997; Pascale et al., 2000). That is a conclusion also reached in medicine (e.g., the brain [Basar, 1990], the heart [Zbilut, Webber, Sobotka, & Loeb, 1993], psychiatry [Boldrini, Placidi, & Marazziti, 1998]). Overall, the ChT fluid perspective—attention to patterns and their process of change (self-organization) is more consistent with the traditional heritage of psychodrama.

ChT and the Morenean Perspectives and Subtheories

Some connections and their implications have already been explored (Carlson-Sabelli, Sabelli, Patel, & Holm, 1992; Remer, 1996, 1998, 2001a, b). Here I briefly indicate the relevance of ChT to psychodramatic theory and offer a broad brush of its main implications. Both need further explication and exploration.

ChT and Psychodramatic Theory Connections

Psychodrama and ChT are both dynamic systems perspectives. I hope that link is apparent by now, so that more extensive ties can be expected. Although a discussion of the translation of each Morenean subtheory (e.g., Moreno, 1951, 1953/1993) might be offered, I mention only the tie between each of the nine constructs and one choice of the psychodramatic subtheories—enactment, role, social atom, sociometry, and spontaneity (e.g., Remer, 1996, 1998, 2000, 2001a, 2001b, 2002b). In each case, I supply an example for the connection.

Phase space and enactment. In each scene, the significant others included and portrayed affect how the situation is viewed and the patterns of interaction produced.

Strange attractors with their basins of attraction and role. Roles are patterns of thought, feeling, behavior, and interaction that fluctuate within certain boundaries chaotically.

Fractals and sociometry. Groups, from dyads to societies and cultures, evidence repetitious patterns of interaction (e.g., members, stars, isolates, rejectees) from level to level; yet, no two patterns are exactly alike.

Self-affinity or self-similarity and role. Role structures (Biddle, 1979) evidence pattern similarities (e.g., positions, role, functions, norms, or expectations) and self-affine patterns of development within and across individuals.

Bifurcation or bifurcation cascade and spontaneity. Each situation offers branchings or variations on old themes; courses of action may proliferate to the point of feeling overwhelming.

Unpredictability and spontaneity. Each situation, novel or otherwise, has unexpected demands.

Recursivity and enactment. Scenes, especially when reenacted, are influenced by previous enactments and reflection on them.

Equilibrium and encounter. Relationships tend to retain certain patterns of interaction unless something happens to upset those patterns at a high enough energy level to demand their change.

Resonance and social atom. Tele influences and is influenced by our responses to others around us, and at times, it is seemingly unrelated to conscious responses.

Self-organization and sociometry. Any group of individuals will develop patterns of organization; additions, losses, changes, and other types of disruptions will produce new patterns that are not entirely planned or anticipated.

Implications of ChT for Psychodramatists

I mention some of the implications of ChT as a motivator for psychodramatists to familiarize themselves with the theory. The fit between the two, because both are dynamic systems, suggests that the approach to human interactions that psychodrama offers may be more consistent with actual reality than other theories (e.g., strict behavioral perspectives). For example, the tolerance of ambiguity and nonpredictability inherent in psychodramatic enactments promotes open exploration with the acceptance of whatever outcomes.

The strong implication that group-oriented interventions may capitalize on chaotic patterns and dynamics better than individual approaches bodes well for psychodramatists. This implication has significant ramifications for a managed-care environment, but it would, no doubt, engender much resistance from establishment perspectives.

Emphasis on spontaneity, as a coping mechanism for dealing with chaotic patterns and as a positive slant on chaos, is extremely important. With more and more stress on positive approaches to human interactions (e.g., well-being and resiliency), psychodrama spontaneity training has much to offer.

ChT has much to say about the view we take of science and specifically of substantiation. Psychodramatic theory has been assailed for its looseness through such empirically substantiated and validated approaches as Dialectical Behavior Therapy. Psychodramatists seem to have a difficult time adapting to the rigorous demands for scientific proof, perhaps because engagement in psychodrama encourages a less restrictive worldview, which some see as less disciplined. Perhaps the difficulty is not entirely with psychodramatists as social scientists, but rather with the scientific paradigm employed. ChT implies that research might be effectively conducted in a way similar to the way Moreno suggested that it be conducted—more inclusively and subjectively. Instead of searching for the impossible to achieve through a limiting approach—universal, immutable laws for human patterns—psychodramatists should be seeking possibilities, flexibility, and variability by using the tools that they know best. Psychodramatists should be using a group, cocreative, spontaneous approach, much like that conceived by Moreno (1951) in his Sociometric Method.

Conclusion

In this article, I have merely scratched the surface, but I hope I have laid a sufficient foundation to support the importance of ChT to psychodrama and the importance of psychodrama to ChT-oriented interventions. The marriage may have been made in heaven—at least as much as any marriage is. Significantly more is left to be said about this joining of ChT and psychodrama. Still more is left to be done, explored, contemplated, and conceptualized.

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