

# *Chaos/Complexity Science and Second Language Acquisition*

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*There are many striking similarities between the new science of chaos/complexity and second language acquisition (SLA). Chaos/complexity scientists study complex nonlinear systems. They are interested in how disorder gives way to order, of how complexity arises in nature. 'To some physicists chaos is a science of process rather than state, of becoming rather than being' (Gleick 1987: 5). It will be argued that the study of dynamic, complex nonlinear systems is meaningful in SLA as well. Although the new science of chaos/complexity has been hailed as a major breakthrough in the physical sciences, some believe its impact on the more human disciplines will be as immense (Waldrop 1992). This belief will be affirmed by demonstrating how the study of complex nonlinear systems casts several enduring SLA conundrums in a new light.*

## INTRODUCTION

Science exists to explain the fundamental order underlying nature. The most valued explanations have taken the form of cause and effect linkages. For example, Isaac Newton was able to find a cause for the movement of the stars in his simple laws of motion and theory of gravity. Faith in science to account for such a deterministic universe inspired French mathematician Pierre Simon de Laplace to claim that if scientists knew the positions and velocities of all the particles in the universe, they would be able to predict the future for all time (Hall 1993).

Two major developments in the twentieth century have laid rest to such claims. The first was Heisenberg's uncertainty principle, introduced into quantum physics to describe the limits to which anything at the quantum level could be known for certain. Laplace's claim rested on the condition that scientists be able to measure the position and velocities of all particles in the universe. Heisenberg demonstrated that at the quantum or subatomic level scientists can ascertain either the position or the momentum of a particle, but not both simultaneously, making prediction impossible.

The second development discrediting Laplace's claim came more recently with the discovery of another kind of unpredictability in nature—the unpredictability which accompanies much larger, more complex, nonlinear systems. For instance, it is well known that such global phenomena as the weather do not lend themselves to trustworthy forecasts, not at least at the proximate, local level. It had always been assumed, however, that such forecasts would ultimately be possible when meteorology or the instruments employed in its

pursuit became sufficiently sophisticated. This assumption proved unsound when it was discovered that with certain such phenomena, randomness was inherent, gathering more information did not obviate it.

The randomness generated by complex systems has come to be called chaos. The study of chaos and the study of the complex systems that manifest it have, according to some, shaken science to its foundation. For the first time, an alternative to the linear, reductionist thinking that has dominated science since Newton appears possible. With access to the computational power of micro-computers, previously intractable problems such as the dynamics of nonlinear systems can be studied. Although such studies have originated in the physical sciences, researchers working in these areas believe that their theories have the potential for immense impact on the more human sciences (Waldrop 1992: 12–13).

The purpose of this article is to call attention to the similarities among complex nonlinear systems occurring in nature and language and language acquisition. While the value of the analogy may only be metaphoric, sometimes 'you don't see something until you have the right metaphor to perceive it' (Bowers 1990: 132, see also Edge 1993).<sup>1</sup> It is my hope that learning about the dynamics of complex nonlinear systems will discourage reductionist explanations in matters of concern to second language acquisition researchers. To this aim, I will begin the article by describing features of complex nonlinear systems that chaos/complexity scientists have identified. Next, I will demonstrate that these same features are characteristic of language and language acquisition. By way of illustrating the value of seeing language acquisition as a dynamic, complex and nonlinear process, I will then offer several examples of questions in SLA which might be addressed from this new perspective. Finally, I will conclude by making some personal observations on the implications of this perspective for development of the SLA field.

#### FEATURES OF COMPLEX NONLINEAR SYSTEMS

The systems discussed in this paper can be characterized to varying degrees by the following features: they are dynamic, complex, nonlinear, chaotic, unpredictable, sensitive to initial conditions, open, self-organizing, feedback sensitive, and adaptive. In addition to these ten characteristics, such systems possess strange attractors, which are fractal in shape. I will discuss these features in clusters.

##### *Dynamic, complex, nonlinear*

Chaos theory, catastrophe theory (Thom 1972),<sup>2</sup> plectics (Gell-Mann in Berreby 1994), dynamical systems theory (Abraham 1994), and complexity theory are all concerned with the behavior of dynamic systems (systems that change with time). As Gleick (1987: 5) puts it: 'the study of chaos is a science of process rather than state, of becoming rather than being.'

Now the study of dynamic systems is not new in science. What makes these theories innovative is that their focus is complex systems. These systems are

termed complex for two reasons. The first follows from what we normally associate with the term 'complex'. Complex systems often, though not always, comprise a large number of components or agents (Davies 1988: 22). An example is the human brain comprised of billions of neurons. The second reason such systems are called complex is one that might not be as obvious. The behavior of complex systems is more than a product of the behavior of its individual components. In complex systems, each component or agent 'finds itself in an environment produced by its interactions with the other agents in the system. It is constantly acting and reacting to what the other agents are doing. And because of that, essentially nothing in its environment is fixed' (Waldrop 1992: 145). In other words, the behavior of complex systems emerges from the interactions of its components, it is not built in to any one component.

That the behavior is emergent is perhaps best illustrated by Craig Reynolds' work on 'artificial life' (Waldrop 1992: 241-2). In his computer simulation 'boids', Reynolds attempted to capture the essence of flocking behavior in birds. Each 'boid' followed three simple rules having to do with separation, alignment, and cohesion (Reynolds 1996). What was noteworthy about the rules was that they were all local, all of them were behavioral instructions for the individual agents to follow relative to the other agents in their vicinity, none of them said 'Form a flock.' Nevertheless, when all the agents invoked the rules concurrently, a flock pattern at the global level emerged. Thus, the traditional approach to science which attempts to understand the behavior of the whole by examining its parts piecemeal is inadequate for studying complex systems. The behavior of complex systems arises from the interaction of its components or agents.

Complex systems are also nonlinear. A nonlinear system is one in which the effect is disproportionate to the cause. Conversely, in a linear system a cause of a particular strength results in an effect of equal strength. When a spacecraft is nudged into orbit by firing its thruster rockets, a linear system is responsible. Nonlinear systems can also sometimes exhibit linearity, however, at other times, they may react in a way that is all out of proportion to the cause. A rolling pebble, for example, can trigger an avalanche. This has been termed the 'camel's back' effect. A simple trigger, one which occurs all the time, might be enough on any given occasion to bring about a great convulsion in the system, or to throw the entire system into a chaotic state.

*Chaotic, unpredictable, sensitive to initial conditions*

Chaos refers simply to the period of complete randomness that complex nonlinear systems enter into irregularly and unpredictably. A milder, more benign image than an avalanche to illustrate this concept is that of water dripping from a spigot. With a slight twist of a faucet, the water falls in a regular, even drip. Given slightly more pressure, the drops, while still falling separately, fall in a never-repeating pattern. The periodic drip has given way to a random-seeming pattern (Crutchfield, Palmer, Packard, and Shaw 1986).

While this chaos may seem predictable—i.e. it always happens when I turn

the faucet—the onset of the randomness of complex nonlinear systems is in fact unpredictable. That the randomness will occur is predictable, what is not is exactly when it will occur. We know that avalanches are caused by sliding rock, but it is impossible to predict which rolling pebble will be the one to unleash a massive slide. So it seems that complex nonlinear systems do behave in a regular, orderly way until a critical point is passed, and then they go chaotic. Following such an episode, they may return to order (Briggs 1992: 19–20).

A major reason for the unpredictable behavior of complex systems is their sensitive dependence on initial conditions. A slight change in initial conditions can have vast implications for future behavior. Indeed, the behavior of systems with different initial conditions, no matter how similar, diverges exponentially as time passes. A phenomenon known popularly as ‘the butterfly effect’ exemplifies this feature and underscores the interdependence of all the components in the system. The butterfly effect is the notion that a butterfly fluttering its wings in a distant part of the world today can transform the local weather pattern next month. ‘Tiny differences in input could quickly become overwhelming differences in output’ (Gleick 1987: 8).

*Open, self-organizing, feedback sensitive, adaptive*

One of the most discussed laws in physics has been the second law of thermodynamics. The second law states that systems inevitably move towards equilibrium. ‘And once a system has reached this lowest or equilibrium state, it tends to remain there forever—a uniform, undifferentiated murk’ (Churchland 1988: 168) with no form, no pattern, no differentiation. The second law was thought to be inexorable. In 1854, German physicist von Helmholtz carried this law to its logical conclusion: the entire universe would eventually, irreversibly, run down or increase in entropy.

At the end of the last century, however, a countermovement grew among biologists, who studied the development of living systems. They observed that living systems were evolving in the opposite direction: from disorder into order. Since Darwin, biologists have seen natural selection as virtually the sole source of that order. Then, in the middle of this century, the chemist Prigogine (who later earned the Nobel Prize for his discovery) was able to demonstrate that there was another source of the shift from disorder to order. Provided that complex systems are open and far from the point of equilibrium, spontaneous large-scale restructurings take place in systems that counter the forces of entropy and create new regimes of order and structure (Smith and Gemmill 1991). How order arises in nature is the central question of the science of complexity today.

What scientists now believe to be true is that the second law applies only to closed systems, systems left to themselves, the object of study of conventional physics. With open systems, systems that are open to new matter and energy infusions, entropy is not inevitable. As open systems evolve, they increase in order and complexity by absorbing energy from the environment. An example in modern cosmology is what transpired after ‘the big bang’. From the

formless miasma of the big bang, the universe has managed to bring forth structure on every scale galaxies, stars, planets, bacteria, plants, animals, and brains (Waldrop 1992 10) Thus, if a nonlinear system is open to a continuous flow of energy, far from its point of equilibrium, then entropy is avoidable 'The flux pumps the system It forces the system away from its initial chaos, and toward the many forms of order and complexity of which is it capable' (Churchland 1988 .169) In fact, unpredictably, highly organized states can suddenly appear

Near to thermodynamic equilibrium a hot solid or gas behaves like an ordinary lamp with each atom emitting a light randomly and independently The resulting beam is an incoherent jumble of wave trains each a few metres long It is possible to drive the system away from equilibrium by 'pumping', which is a means of giving energy to the atoms to put an excessive number of them into excited states When this is done a critical threshold is reached at which the atoms suddenly organize themselves on a global scale and execute cooperative behavior to a very high level of precision Billions of atoms emit wavelets that are exactly in phase, producing a coherent wave train of light that stretches for thousands of miles (Davies 1988 82)

What results is a laser—an example of a self-organizing system, in which particles of light spontaneously group themselves into a single powerful beam

The order such systems exhibit is shaped by the fact that they are also feedback sensitive Perhaps it is in the field of biology where this feedback sensitivity can most readily be perceived Darwin's great insight was to posit the existence of a basic feedback mechanism built into nature, namely, natural selection The steady improvement of a species was called evolution (Waldrop 1992 179) 'Positive feedback kicks evolution forward Meanwhile, negative feedback in evolution keeps mutation changes from spiraling out of control—the checking power of many negative feedback loops simply wipes out most mutations and keeps the design of the species stable for long periods of time' (Briggs 1992 117)

It is in the capacity to naturally select and to self-organize that we say complex systems in biology are adaptive (Kauffman 1991) They do not simply respond passively to events, they actively try to turn whatever happens to their advantage They are capable of learning, although 'the process of learning—testing a model against reality and then modifying it to suit—occurs at different time scales throughout biology' (Berreby 1994 26)

### *Strange attractors, fractal shape*

The path that a dynamic system takes can be traced in space and is called an attractor It receives this name because it is the pattern to which a dynamic system is attracted For example, in a closed system, where there is no influx of energy, a bob swinging on the end of a string has a fixed point attractor, eventually the bob will settle down, stop swinging and be 'attracted' to a fixed point A frictionless pendulum, on the other hand, yields a periodic or limit

cycle attractor Its attractor is an orbit defined by the two extremes at either end

A complex nonlinear system exhibits a different attractor altogether, one which was until recently unknown Such a system has a 'strange' attractor because although its cycle repeats itself like the frictionless pendulum, no cycle ever follows the exact same path or overlaps any other cycle 'The orbits can become very densely packed together, and can in fact approach infinite thinness, but are still constrained within the limits of the attractor' (Taylor 1994 203) Thus, globally a pattern emerges, but locally it is impossible to predict just what the details will look like For instance, at the same time that the weather is constantly changing, it also stays within the boundaries of what we call the climate<sup>3</sup> 'We can tell where the system cannot be, and we can identify the states that the system is most likely to be, but we cannot tell exactly where the system will be' (Mohanam 1992 650) As such, a strange attractor can be depicted as 'stochastic behavior occurring within a deterministic system' (Stewart 1989 17)

If an attractor is a way of representing the behavior of a system in geometrical form, it stands to reason that different systems will yield geometric figures While this is true enough, all strange attractors have something in common—their shape is geometrically a fractal, a term coined by the geometer, Benoit Mandelbrot, to mean a fraction that includes all A fractal is a geometric figure that is self-similar at different levels of scale The example I have found most helpful to illustrate a fractal is that of a tree Trees come in all sizes and shapes, it is impossible to predict the exact dimensions of a tree or where the branches (if any) will radiate from the trunk Not all trees have leaves, and even if they did, we could not predict how many leaves there would be growing from which twigs on which branches, etc None the less, the combination of arboreal shape, location, behavior, makes us unquestioningly recognize something as a tree A tree is an example of a complex nonlinear system and *ipso facto* we know that it is a fractal

It is not difficult to see how a tree is self-similar at different levels of scale When you gaze at a tree, you see a central trunk and branches spreading out from it If you were to focus in on a single branch, you would adopt a perspective, one different in scale, but one which yielded essentially the same shape, namely a central stalk and radiating smaller offshoots Of course, in this case, the offshoots are twigs When in turn, you look at a twig, the same pattern repeats itself, with a leaf likewise, you would find a central vein with 'arteries' radiating outwards Thus, as you zoom in on any level of magnification, it always reveals a reproduction of itself

To help with this concept, one might also think of a weather map. Whether it is a map of a large region, such as that taken from a camera mounted on a satellite, or whether it is more of an aerial shot, or even one of the weather scene right above your hometown, the pictures would look very much the same at different levels of scale some swirling white clouds, some clear patches, etc

'These patterns illustrate the fact that the system's whole movement takes place continuously at every scale' (Briggs 1992: 24)

#### COMPLEX NONLINEAR SYSTEMS AND LANGUAGE

The study of complex nonlinear systems and the study of language have much in common. While language can be conceptualized as aggregations of paradigmatic and syntagmatic units (e.g. phonemes, morphemes, sentences, etc.), it is also true that a view of language as a dynamic system can be adopted. Saying that language is dynamic borders on the banal for the two usual interpretations of the 'dynamic' quality of language are well known. The first common meaning of dynamic as applied to language is that of process—language can be described as an aggregation of static units or products, but their use in actual speech involves an active process, usually referred to as *parole* (Saussure) or performance (Chomsky). Larsen-Freeman (1991b), for example, has coined the term 'grammaring' to capture the dynamism of grammar in use. Such an observation is not without precedent in linguistics. Humboldt (1949 cited in Robins 1967)<sup>4</sup> stresses that 'a language is to be identified with a living capability by which speakers produce and understand utterances, not with the observed products of the acts of speaking and writing' (Robins 1967: 174). Halliday (1985), too, has observed that we would be better served with more dynamic models of grammar. Current popular models do not capture well the dynamism and variability of language in use.

The other common way that language is perceived to be dynamic is when dynamic is equated with growth and change. Adopting this view of language, Rutherford (1987) suggests that for certain purposes, a better metaphor for language than a machine might be an organism, machines are constructed, organisms grow (Rutherford 1987: 37). Rutherford's suggestion brings to mind Schleicher's (1863 cited in Robins 1967) treatise on Darwinian theory and linguistics in which he regards language 'as one of the natural organisms of the world to be treated by the methods of natural science, one moreover that independently of its speakers' will or consciousness has its periods of growth, maturity, and decline' (Robins 1967: 181, see also Pinker and Bloom (1990) for a modern day treatment of language employing the biological metaphor of evolution). Whether one is comfortable with the animism Schleicher ascribes to language or not, the point is that language, seen not only from a synchronic, but also from a diachronic perspective, is undeniably dynamic.

Furthermore, the changes which languages undergo diachronically are nonlinear. New forms enter and leave the language in a non-incremental fashion. Moreover, they do not do so uniformly, so that a synchronic snapshot of language might appear chaotic: different speakers of the language using different forms to mean the same thing. Which new forms are introduced into the language is not completely predictable. We can anticipate change to some extent by noting that innovations, such as new developments in technology, for example, are accompanied by an expansion of lexis to refer to the new concepts or products. We might also look to areas around which

there is some insecurity on the part of native speakers (such as the choice between using object pronouns or subject pronouns in English) to understand why some native speakers of English appropriate other forms in order to avoid the choice (for example, English speakers increasingly use reflexive pronouns today for both object pronouns and subject pronouns *Between you and myself* or *Alex and myself went* ) The point is, however, that the best we can do is explain the occurrence of change *a posteriori*, not actually look at the language and make exact predictions of what change will transpire next

While the word dynamic to mean 'synchronic process' and 'diachronic growth/change' can also be used to describe the complex systems discussed in this paper (recall the earlier quote from Gleick about 'process' not 'state' and 'becoming' not 'being'), there is yet a third interpretation of dynamic, which is inspired by a chaos/complexity theory perspective, and which is not commonplace, although not unknown, in the way language is usually construed This third meaning of dynamic makes no distinction between current use and change/growth they are isomorphic processes Every time language is used, it changes As I write this sentence, and as you read it, we are changing English 'The act of using the language meaningfully has a way of changing the grammar system in the user' (Diller 1995 116) Moreover, as the user's grammar is changed, this sets in motion a process, which may lead to change at the global level<sup>5</sup> Rather than using rules to shape discourse, the rules themselves are shaped by the discourse<sup>6</sup> Thus, the behavior of the system as a whole is the result of the aggregate of local interactions 'A language such as English is a collaborative effort of its speakers, and changes in the system of English are "emergent"' (Diller 1995 117) As Gleick (1987 24) has put it 'the act of playing the game has a way of changing the rules'

Such a view suggests that language grows and organizes itself from the bottom up in an organic way, as do other complex nonlinear systems While rules can be used to describe such systems, the systems themselves are not the product of rules<sup>7</sup> In order to understand the dynamics of this 'bottom-up approach', computer scientists have shifted the way they represent the brain from a computational to a connectionist model By no longer conceiving of the mind as requiring a central program to direct it and to select the appropriate rules to apply, an entirely different theory of mind can be entertained

The arborization of the dendrites, the chaotic firing of neurons in the motor cortex, and at least the beginnings of an experimental and a modeling literature suggesting that nervous tissue has fractal geometrical, statistical, and dynamical properties have led neuroscientists to begin to model the brain as a complex, nonlinear system According to this model, there are weights on the excitatory and inhibitory connections between nodes Given certain sensory input, certain connection weights will be strengthened Weights are thus tunable, they fluctuate from second to second At any given time, the weights are settling into or moving away from certain states



States that the networks tend to move away from are called 'repellers' and states into which the networks 'settle' or 'relax' are called 'attractors' No information is being processed in such an evolution of states This spontaneous process is stochastic attractors are associated with a certain probability that the net will settle there, but the settling process is unpredictable It is of fundamental importance that this spontaneous stochastic movement toward attractors is *not rule governed* Connectionist machine operations (i.e., performance) do not follow rules (even though the machine's competence can be so described) There is no program that determines which state the net will likely settle into, this is quite unlike the case for computers [heretofore which were modeled on a computational theory of the mind] which are heavy with necessity, permitting no exceptions Instead the net spontaneously *self-organizes* toward attractor states, and under certain conditions, may even enter states never before achieved Neural nets are light with possibility (Globus 1995 23-4)

Thus, previously 'the "information" of computers [i.e., programs of the input-output sort] ha[d] to do with data structures as strings of exact symbols, i.e., *representations*, that can be logically processed, in contrast, the 'information' of dynamical systems is very different [it] has to do with changes in *knowledge* about the system, i.e., with change in our uncertainty about the system state Brain chaos, then, turns us away from computer computation toward performance systems naturally described by nonlinear dynamics' (Globus 1995 99)

It must now be apparent why I have given so much attention to the third interpretation of the term dynamic It is this very quality which portends to alter in a fundamental way our model of the brain and our conception of language A static algorithm cannot account for the continual, and never-ending growth and complexification of a system that is initiated from the bottom-up It cannot account for the performance 'inconsistencies of competing dialects and registers', nor the 'improvisational metaphors of ordinary language usage' (Diller 1995 112) To do so, a dynamic model of performance is needed, which relates individual use to systemic change We need not therefore await development of a theory of *langue* or competence before tackling the study of *parole* or performance Indeed, they cannot be studied independently of each other if we want to be faithful to the reality of language (Bernàrdez 1995) To conclude this portion of the paper, I will briefly review other qualities of dynamic systems, which were discussed in the first section of this article, and which also hold true for 'language in my opinion

As is true of other dynamic nonlinear systems, language is also complex It satisfies both criteria of complexity first, it is composed of many different subsystems phonology, morphology, lexicon, syntax, semantics, pragmatics Second, the subsystems are interdependent A change in any one of them can result in a change in the others (Larsen-Freeman 1989, 1991b, 1994) In other words, the behavior of the whole emerges out of the interaction of the subsystems Thus, describing each subsystem tells us about the subsystems, it does not do justice to the whole of language

Complex nonlinear systems exhibit sensitive dependence on their initial

conditions, and language is no exception. We might call UG the initial condition of human language—it contains certain substantive universal principles that apply to constrain the shape of human languages. For instance, there are a small number of archetypal or core phonological patterns that apply to all languages, e.g. almost all languages have voicing assimilation of obstruents. These are powerful principles which have a huge impact on defining the 'strange attractor' of human language. However, languages also differ. In English, the voiced consonant assimilates to the voiceless, whereas in Spanish and Russian, the first consonant assimilates to the second regardless of the voicing feature (Mohan 1992). To explain interlinguistic differences like this in a manner consistent with the view being proposed in this article, Mohan posits UG 'fields of attraction' that permit infinite variation in a finite grammar space. Fields of attraction are by nature gradient, unlike parametric choices which are generally seen to be discrete. The strength each field exerts on a particular language differs thus allowing for interlinguistic variation. For any given language, the fields of attraction will define the state that the system is attracted to, i.e. its most natural or unmarked state. Because of them, the changes a language undergoes leave its basic shape intact. Therefore, anything borrowed into the language will be adapted to conform to the permissible phonological sequences and sometimes to the morphosyntactic constraints as well (e.g. *aisukurumu* of Japanese and *Le Drugstore* of French, borrowed from English).

Just as the strange attractors of complex nonlinear systems are fractals so language is a fractal. In fact, all information systems need to be fractal in shape in order to make them compressible and thus shareable (Winter 1994). In truth, it is its fractality that makes available an infinite amount of behavior or information within a closely circumscribed space (Taylor 1994: 203). Language then, is no different from other natural phenomena in that its form follows function.

An example of the fractality of language can be seen in Zipf's power law connecting word rank and word frequency for many natural languages. This law states that, 'to a very good approximation, relative word frequency in a given text is inversely proportional to word rank  $r$  where  $r$  is the  $r$ th word when the words of a language are listed with decreasing frequency' (Schroeder 1995: 35). In other words, if a word occupies a particular word frequency rank in a given language, then it is likely to reflect that same frequency in any given text of that language. Zipf's law is apparently not only applicable to a language in general, but also to specific writers. 'For a very competent writer with active vocabulary of 100,000 words, the 10 highest-ranking words occupy 24 percent of a text, while for the basic (newspaper?) English with one-tenth the vocabulary (10,000 words), this percentage barely increases (to about 30 percent)'. Thus, we see in Zipf's law the self-similarity of scale in language that is intrinsic to fractals in the natural world. The pattern that exists at one level of scale holds for other levels and for the whole system. Furthermore, changes are taking place continuously and these, too are reflected at every level of scale. As

I am writing this article I am contributing to the changing frequencies of word use in this article and to those in the whole system of English<sup>1</sup>

#### COMPLEX NONLINEAR SYSTEMS AND SECOND LANGUAGE ACQUISITION

There are a number of parallels between complex nonlinear systems and second language acquisition (SLA) as well. First of all, both are characterized by dynamic processes. Indeed, a challenge in SLA research has been how to capture, with any formalism, the dynamism in evidence in the evolution of learner interlanguages (ILs). Researchers' grammars containing static rules do not do justice to the ever-changing character of learners' internal L2 grammars.<sup>8,9</sup> The third definition of dynamic also holds for learners as it does for proficient speakers of a given language: by virtue of using the target language, it is transformed. Indeed, the very phrase 'target language' is misleading because there is no endpoint to which the acquisition can be directed.<sup>10</sup> The target is always moving.<sup>11</sup>

The SLA process is also known to be complex. There are many interacting factors at play which determine the trajectory of the developing IL:<sup>12</sup> the source language, the target language, the markedness of the L1, the markedness of the L2, the amount and type of input, the amount and type of interaction, the amount and type of feedback received, whether it is acquired in untutored or tutored contexts, etc. Then, too, there is a multitude of interacting factors that have been proposed to determine the degree to which the SLA process will be successful: age, aptitude, sociopsychological factors such as motivation and attitude, personality factors, cognitive style, hemisphericity, learning strategies, sex, birth order, interests, etc. (Larsen-Freeman and Long 1991). Perhaps no one of these by itself is a determining factor,<sup>13</sup> the interaction of them, however, has a very profound effect.

Further, learning linguistic items is not a linear process—learners do not master one item and then move on to another. In fact, the learning curve for a single item is not linear either. The curve is filled with peaks and valleys, progress and backsliding. The classic example of this is when beginners acquiring English correctly produce the past tense of irregular and regular verbs. It is thought that these are mastered incrementally at a lexical level, i.e. learners learn one verb and its ending at a time. After further exposure to the target language, however, chaos ensues. No one knows for sure when it might strike, but sooner or later it takes only one more instance in the input of a past tense verb 'to break the camel's back'. The result is that where once the interlanguage was characterized by many examples of correct past tense, a period of seemingly random suppliance of the *-ed* follows, often the *-ed* is overgeneralized to irregular verbs, e.g. *sitted*, *eated*, *sleeped*, where earlier correct targets were being produced.<sup>14</sup>

Given that the system is open, however, and given that there is continued input, the interlanguage system is self-organizing and the chaos with regards to the past tense ending, at least (presumably there are oscillating cycles of lesser and greater chaos going on elsewhere in the system), subsides.<sup>15</sup> In second

language acquisition research terms, we speak of the 'restructuring' of this aspect of the interlanguage, the return to order, which has taken place. The restoration of order is aided by the fact that the system is feedback sensitive. The absence of positive evidence in the environment or the explicit provision of negative evidence can help learners adapt their interlanguage grammar closer to that of target language users. Conversely, we might say that the absence of learning in a language, fossilization, occurs when the learners' grammar system becomes closed and settles down to a fixed point attractor.<sup>16</sup> 'In biology, of course, the agents are individual organisms, the feedback is provided by natural selection, and the steady improvement of the models is called evolution. But in cognition, the process is essentially the same: the agents are individual minds, the feedback comes from teachers and direct experience, and the improvement is called learning' (Waldrop 1992: 179).

While interlanguages of speakers of various first languages learning English as a foreign language have much in common, they also are distinctive, each constrained by the strange attractors of their L1s, which may be greater than the force of the strange attractor of English. Thus, the English pronunciation of a native speaker of Spanish will differ from that of a native speaker of Chinese. Many other fundamental differences mark the challenges present for learners from one native language background as compared with another. Besides the obvious linguistically-based differences are the learners' cultural backgrounds and reasons for learning (not learning) a second or foreign language in the first place.

Now, the case that I have been attempting to make for the parallelism between complex, dynamic non-linear systems and language/language acquisition may strike some readers as too glib. I confess to some uneasiness with it myself. There is a danger when a new theory comes into being that it can be made into a theory of almost anything. And I plead guilty, as I have already applied it in this article to language, the brain, and second language acquisition. Many believe that the promise of chaos/complexity theory is overly optimistic (Horgan 1995). Perhaps my enthusiasm has caused me to exaggerate its scope of influence. If for the moment, however, we suspend our doubts (Larsen-Freeman 1983) and entertain the thought that language and language acquisition are like other complex systems in the physical sciences, what do we stand to gain? In reply, let me say that I believe there are issues in SLA that might be illuminated by such a perspective. By way of illustration, I will limit my discussion to five examples: mechanisms of acquisition, definition of learning, the instability and stability of interlanguage, differential success, and the effect of instruction.

#### QUESTIONS IN SLA TO BE EXAMINED FROM THIS NEW PERSPECTIVE

##### *Mechanisms of acquisition*

Seeing language as a complex nonlinear system may cause us to re-evaluate our assumptions about the basic mechanisms (Long 1990) operating in SLA. For

example, a chaos/complexity theory perspective has some bearing on the long-time disagreement concerning language acquisition between innatists and constructivists over what must be hardwired in the brain and what must be present in the environment for language acquisition to take place. In the debate between Piaget and Chomsky (Piatelli-Palmerini 1980: 140), you may recall, Fodor, adopting an innatist stance, claimed that 'it is never possible to learn a richer logic on the basis of a weaker logic, if what you mean by learning is hypothesis formation and confirmation'. The same point could be made about hypothesis selection—i.e. setting the parameters of universal principles—which is triggered by exposure to input. For underlying both is the assumption that the complexity of the final state (grammar) cannot exceed the complexity of the combination of the initial state (universal grammar) and the input (data to which learners are exposed).

the output of LAD contains principle P. Principle P could not have been inductively arrived at from the input. Therefore, it must have been innately specified as part of LAD. For this conclusion to be valid, we need to appeal to the hidden assumption that every organizational principle found in the output must be present either in the initial state (LAD) or in the input (data). That is to say, LAD is essentially entropic: the complexity of the output cannot exceed the sum total of the complexity of the input and the initial state. (Mohanani 1992: 649–50)

But, we have already seen that entropy is not inevitable in complex, nonlinear systems. What if language is an example of one of these systems? What if the input data triggers the creation or formation of novel complexities—complexities beyond the complexity of the input? Note that the key word here is 'complexity'. It is well established that both L1 and L2 acquirers produce novel forms, forms they would not have heard in the input, such as the use of *goed* for *went* by learners of English. Mohanani's point, however, is that the novel forms produced by the acquirer are sometimes more formally complex than the target language input, and he asks, rightly, I think, where the complexity comes from.<sup>17</sup>

While neither hypothesis formation nor hypothesis selection may satisfactorily explain the increasing complexification of the learner's system, simple connectionism may offer little assistance in this matter either. A connectionist model can generate new forms—forms that were not present in the input, however, it does so by analogizing from input data to new domains. It seems it cannot explain complexity in the output that is not data driven. We might be better served, then, to think of language acquisition, Mohanani (1992) advises, not as deduction from the adult grammar in the face of available input, nor as pattern matching and extension by analogy, but rather as pattern formation or morphogenesis. However, there is an issue with morphogenesis as well. If language acquisition is a process of pattern formation, and if patterns can be created spontaneously that are more complex than the input data, how is it possible for us to comprehend one another? Why do we not each wind up creating our own language, speaking mutually unintelligible idiolects?

The first answer to this question is that the process of pattern formation happens within a system which constrains its general shape. The second answer is that grammars of speakers in the same community *adapt* to each other. Recall that *adaptation* is also an inherent quality of dynamic, complex nonlinear systems. To sum up Mohanan's position:

The emergence of order/complex organization in linguistic systems is analogous to the emergence of order/complex organization in nonlinguistic systems. The formation of grammar in an individual does not involve a logical problem of deducing propositional knowledge, but involves growth of form in a system that governs the external behavior of the system. Linguistic patterns appear spontaneously in the language faculty, when triggered by the environment, like patterns in snowflakes. Unlike snowflakes, however, linguistic systems exhibit adaptability. Their internal changes are governed by the pressure to conform in their overt behavior to those of the other members of the community (Mohanan 1992: 654–5).

In other words, both individual creativity and social interaction<sup>18</sup> combine to influence the shape of the developing grammar. As intuitively appealing as this is, it may very well be that this newest characterization of the acquisition process—morphogenesis and adaptation—will not withstand the test of time. Also, we would need to determine its relevance for the *second* language acquisition process. Then, too, we need to ask how different this view is from that of Schumann's (1978a) creolization or Andersen's (1983) nativization, processes which purport to involve the creation of a linguistic system at least partly autonomous from the input language. Finally, I see no reason, myself, to abandon hypothesis formation, selection, or analogical reasoning at this point as potential mechanisms involved in SLA. If language is as complex as it is, it is not likely we will find a single process to account for all of the complexity. Nevertheless, I offer morphogenesis-with-adaptation as an example of my point that by embracing a view of language/language acquisition as a complex nonlinear system, we are encouraged to expand our quest for explanatory mechanisms for second language acquisition.

#### *Definition of learning*

How to determine when something has been learned is a very difficult question. My SLA students are amused at the lengths to which SLA researchers go to claim that learning something has taken place. Hakuta (1974), for example, adapting Cazden's definition to his own longitudinal study defined the point of acquisition as the 'first of three consecutive two-week samples in which the morpheme is supplied in over 90% of obligatory contexts'. While this definition is a commendable attempt at operationalizing 'learning', it is flawed, as all such measures are, by limiting learning to target-like production.<sup>19</sup>

But flawed as it is, at least this definition attempts to remain true to the nonlinear nature of the SLA process. It allows for backsliding, for instance. However, much of SLA research is not of a longitudinal nature. Learning is said to have occurred if the subjects' performance on a post-test exceeds that of

their pre-test. The treatment is alleged to have failed if no gain or negative gain is recorded. For instance, UG researchers, studying the value of negative evidence in aiding learners to reset the parameters of their L1 to the new parameter settings for the L2, have been criticized for failing to show that learners who receive negative evidence made long-term learning gains. Based on the fact that the subjects' performance on a distal post-test was not significantly different from their performance prior to the treatment (i.e. the suppliance of negative evidence), the detractors conclude that the 'grammar-building process cannot make use of negative evidence to restructure interlanguage grammars' (Schwartz and Gubala-Ryzak 1992). I, for one, am not sure.

Remember the unleashing-of-the-avalanche image from chaos theory. Many pebbles may roll before the avalanche is set off. With simple pre-test/post-test designs, how will we know if our treatment is an ordinary pebble, or an avalanche trigger? Much learning may take place receptively only to be manifest productively when the requisite data have been taken in. Terrell (1991), Ellis (1993), and Van Patten and Cadierno (1993) have all pointed out that explicit grammar instruction will not likely result in immediate mastery of specific grammatical items, but suggest nevertheless that explicit instruction does have value, namely, in facilitating intake.

Recognition of the definition of learning issue becomes even more urgent when we think about the way we assess language learning. First of all, such assessment is usually done by measuring the target-like appearance of forms. Others have already pointed out the target-centric nature of this enterprise (e.g. Bley-Vroman 1983). *This problem is further compounded because as we have already seen, the learners' internal grammar may have changed without the learners' being able to produce a new form—maybe the triggering pebble has yet to roll.* Finally, what has been learned is not a steady state any more than the target language, and learning is therefore always provisional.

#### *The stability/instability of interlanguage*

Much effort in SLA has gone into addressing such questions as 'What does systematic mean?' and 'How can an interlanguage be termed "systematic" when in most researchers' data, there appears to be so much variability?' 'Is there a cut-off point where the notion of "system" no longer makes sense?' Tarone, Frauenfelder, and Selinker (1976) ask. This question motivated these three researchers to postulate nine logical possibilities between Time 1 and Time 2 by which a learner's IL could be characterized as stable/unstable. Their definitions again made use of the appearance of a given structure in obligatory contexts. The learner's production shows stability when there was no change in the distribution of variants over time. So, for example, one possibility for stability would be where a given variant is supplied  $\leq 10$  per cent, another when the variant was produced  $\geq 90$  per cent in obligatory contexts. An example of instability would be from less than 10 per cent suppliance to variable production. Using their nine definitions, Tarone, Frauenfelder, and Selinker found

definite patterns of instability in the IL of children in French Immersion Programs in Toronto

ILs, like all natural languages, are unstable. There is always spontaneous innovation, and there is always borrowing (Tarone 1990). 'Natural language is unstable and so is subject to invasion by new forms. IL is a special type of natural language in that it is characterized by a very high level of instability. It is subject to constant bombardment by new linguistic forms, many of which are 'taken in', when to begin with they exist side by side with existing forms' (Ellis 1985: 125). If instability is seen to be a threat to systematicity, the position put forth in this article makes matters worse for I am contending that there is even more instability than what surfaces when we recognize that changes are taking place all the time, and that the appearance of novel forms is merely the tip of the iceberg.

While all this instability might have been seen at the time as a threat to the systematicity of IL's, chaos theory is reassuring in this regard. For as Percival (1992) notes, there is *persistent instability* in complex dynamic systems. If we view ILs as complex dynamic systems, a perspective I am advocating, then the problem of reconciling systematicity and instability is eliminated—an unstable system is not an contradiction in terms.

#### *Individual differences*

A major strand of SLA research has been devoted to the study of differential success among second language learners. Researchers have investigated many variables to account for the observation that not all learners are uniformly successful in acquiring a second language. One of the major questions has revolved around the validity and applicability of the instruments used to measure these variables. Are the measures of cognitive style, the Group Embedded Figures Test, for instance, really applicable to language acquisition? Another issue has been the fact that often rather simple univariate analyses, such as simple correlations between a single individual variable and learner performance on some language proficiency measures are used. As d'Anglejan and Renaud (1985) rightly point out, learner variables inevitably overlap and interact with others, suggesting that we are not getting a true measure of a factor if we isolate it from others. This would certainly be the case if language acquisition is a complex nonlinear process.

In addition, Seliger (1984: 37) contends

The more variables we identify, the more we attempt to explain the recombinations of these variables through the wonders of computer and multivariate analysis. While many characteristics have been related correlationally to language achievement, we have no mechanism for deciding which of the phenomena described or reported to be carried out by the learner are in fact those that lead to language acquisition.

Seliger's point is well taken. Progress in understanding SLA will not be made simply by identifying more and more variables that are thought to influence language learners. We have certainly witnessed the lengthening of taxonomies



of language-learner characteristics over the years, and we doubtless will continue to add to the lists Schumann (1976) mentions 4+ factors, by 1989, Spolsky notes 74. However, it is not clear that we have come any closer to unraveling the mysteries of SLA now than before. If SLA is indeed a complex nonlinear process, we will never be able to identify, let alone measure, all of the factors accurately. And even if we could, we would still be unable to predict the outcome of their combination.

### *Effect of instruction*

Much of the SLA research has dealt with natural or untutored acquisition. Prior to the more recent establishment of classroom-centred SLA research, researchers operated under the assumption that instruction was just one more variable to be dealt with (e.g. Schumann 1978b), and that when we better understood acquisition in its natural state, we could factor in the effects of instruction.

While it is common practice when faced with complex systems to deal with one definable part at a time, I do not think that the effects of instruction can be factored in later, any more than learner factors can be included after we have figured out the learning process (Larsen-Freeman 1991a). Remember that in complex nonlinear systems, the behavior of the whole emerges out of the interaction of its parts. Studying the parts in isolation one by one will tell us about each part, but not how they interact.

### CONCLUSION

Analogies are only helpful if by knowing something about one member of a pair, we can advance our understanding of the other. It is too early to tell if chaos/complexity theory has the capacity to shed substantive light on conundrums in SLA the way it has on a wide range of complicated phenomena from biochemical processes, to genetic variation, to economic fluctuations (Hall 1993, Ruelle 1993). Nevertheless, it has the *potential* to contribute to our awareness about various aspects of language and language acquisition.<sup>20</sup> By way of conclusion, then, I will offer a few of the ways that its potential might be realized. It seems to me that chaos/complexity theory

#### 1 *Encourages a blurring of boundaries*

Linguists have identified a number of dichotomies already explicitly or implicitly dealt with in this article: language as mental construct/language as use, *langue/parole*, competence/performance, synchronic/diachronic, innatism/constructivism, individual speaker-hearer/social interaction, etc. Typically, linguists have aligned themselves with one or the other of the members of each pair. Saussure, for example, argues that the linguist's role is to investigate the language system present in language from a synchronic perspective. Chomsky has made it his contribution to argue for a strong innate endowment for language within humans. Vygotsky feels that what is of value lies in social interaction, Chomsky takes the individual speaker-hearer as his focus.

One lesson from chaos theory is that these may be false dichotomies for those interested in the whole of second language acquisition. While it may be essential that the distinctions be preserved for the purposes of linguistic description, chaos/complexity theory encourages a blurring of boundaries in SLA—to see complementarity, and to practice inclusiveness<sup>21</sup> where linguists have seen oppositions and exclusiveness. One of the things I appreciate about a chaos/complexity theory perspective is that it suggests we need to see SLA as *both/and* rather than *either/or*. To cite just one example of a false dichotomy, I have discussed how from a chaos theory perspective, language use and language change are inseparable. Remember ‘playing the game changes the rules’.

### *2 Warns against settling for simple solutions prematurely*

Closely aligned to the first point, but sufficiently important to warrant one of its own, is the need to resist the temptation to settle for simple solutions to complex problems. While it is true that one criterion by which theories are judged is parsimony, a pursuit of simple explanations for a complex process such as SLA at this point in the evolution of the field is at best premature, it seems to me. For example, as I indicated earlier, I think it is entirely possible that there are various mechanisms involved in SLA and we should not assume that SLA is attributable solely to hypothesis formation/selection *or* analogical reasoning *or* morphogenesis/adaptation, *or* even to a combination of the three for that matter.

### *3 Provides some fresh images for SLA phenomena*

As we have seen, biological metaphors are not new in language description. The notion that languages are organic, grow, and evolve has been proposed before the advent of chaos theory. However, chaos/complexity theory provides a fresh reprise on this biological theme and some compelling images to go along with it.<sup>22</sup> The murk and stagnation of entropy, the infinite thinness of strange attractors, the self-similarity of scale in fractals. By drawing an analogy between language and complex, nonlinear systems occurring in nature, it follows that languages go through periods of chaos and order as do other living systems. Furthermore, their creative growth occurs at the border between these two (‘Life at the Edge of Chaos’ is a chapter title in Waldrop 1992: 198). Raising our awareness about the non-entropic nature of language may force us to recognize that mechanisms that are input-data driven cannot adequately account for complexification of the learner’s system beyond that present in the input. Finally, it is intriguing to consider in what ways language is a fractal and what selective advantage is derived from this.

### *4 Foregrounds certain problems, obviates others*

It is clear that we cannot rely on simple pre-test/post-test research designs to measure language gains. Much learning can take place in the form of reduction of uncertainty in the system state without ever manifesting itself in production of a new form. We need to remember the ‘camel’s back’ effect. How to

determine when learning takes place is an old problem foregrounded by what we are learning from chaos/complexity theory

On the other hand, shifting the lens through which we view the world helps us to see that the problem of an unstable system is not a problem after all—that a characteristic of a complex, nonlinear system is persistent turbulence. From a chaos/complexity theory perspective, then, an IL must be conceived as the evolving grammar of the learner adapting to an evolving target grammar, not as one of a set of successive approximations to a steady-state grammar. In other words, we need a camcorder, not a camera to do our research

*5 Discourages theory construction through the aggregation of simple univariate cause-effect links<sup>23</sup>*

We know from chaos theory that complex systems are comprised of many interacting parts, the behavior of which (even the tiniest), when combined, is unpredictable. As such, it is futile to expect that by aggregating findings from simple univariate cause-effect links made in laboratory settings that we can build a theory of SLA that will hold when all the factors are combined. Remember 'the butterfly effect'

*6 Underscores the importance of details*

Because of the sensitive dependence on initial conditions in chaotic systems, we know that the paths of dynamic systems with similar, but not identical, starting points can diverge exponentially at a later time. Thus, chaos/complexity theory underscores the importance of the details. It can be the small things that matter the most. They must not be overlooked.

*7 Reminds us to hold the whole and to find a unit of analysis that allows this*

But as we are focused on the details, we must not lose sight of the whole. Because the behavior of a whole complex nonlinear system is not built into any one of its components, it is self-defeating to examine in isolation a part of the whole in order to learn how the whole operates. However, it is not easy to imagine how one might go about studying the whole of SLA. Thus, it seems we need a way to focus on an individual aspect while respecting the complexity of the whole (Gattegno 1987: 80).

Vygotsky recognized this, of course, which is why he felt that trying to understand consciousness by reducing it to its elementary components was futile. In order to study consciousness, a minimal unit of analysis needed to be established, which was itself a microcosm of consciousness (Lantolf and Appel 1994: 22). Although Vygotsky's choice of word meaning as an investigable microcosm was perhaps misguided (Wertsch 1985), another gift of chaos/complexity theory is recognition of the need for a new unit of analysis within SLA (although the term 'unit of analysis' might itself be inappropriate), which somehow focuses on the particular while embracing the whole.

It is true that some of these thoughts/opinions were with me before I began to read about chaos/complexity theory. Others, though, were inspired by what I

learned Readers of this article will come to their own conclusions, doubtless different from my own So much the better—for with the chaos of conflicting opinion, comes growth

(Revised version received June 1996)

#### ACKNOWLEDGEMENTS

An earlier version of this paper was presented under the title 'On the Parallels between Chaos Theory and Second Language Acquisition' at the Second Language Research Forum, McGill University, Montreal, October 1994 Since then, I have benefited from discussions with my students Craig Sower and Michael Cholewinski about matters discussed herein Thanks also to Kathi Bailey, Lou Spaventa, and Donald Freeman for their comments on an earlier draft of this paper Finally, I am grateful for the feedback provided by the two anonymous reviewers of *Applied Linguistics*, which has helped me in preparing a revised version of this article

#### NOTES

<sup>1</sup> This quote from Bowers is taken from a paper in which he muses on the implications of chaos theory for our field I did not know of this paper when I presented mine in Montreal, but since then have discovered others within our field (Diller 1990, 1995, Lewis 1993, Connor-Linton 1995) who have speculated on the same theme and others within allied fields (Mohan 1992, Taylor 1993, 1994, Bernardez 1995), who have done likewise Where relevant, I will cite these works

<sup>2</sup> I am grateful to Craig Chaudron for drawing my attention to this work

<sup>3</sup> Although 'climatologists worry these days that the weather's strange attractor (the climate) may one day change its shape as a result of the industrial perturbations caused by human beings' (Briggs 1992: 140)

<sup>4</sup> I appreciate my colleague Elka Todeva's reminding me of Humboldt's work

<sup>5</sup> This is the type of change historical linguists try to account for through such means as the great English vowel shift

<sup>6</sup> This explanation for language change is parallel to Hatch's (1978) claim for SLA that out of participation in conversation, learners learn syntactic structures I also think it is a perspective not incompatible with Becker's (1983: 218) suggestion regarding language use 'suppose that, instead of shaping discourse according to rules, one really pulls old language from memory and then reshapes it to current context' And Becker cites Bateson's (1979: 17) thought that 'context shaping is just another term for grammar'

<sup>7</sup> See Rumelhart and McClelland (1986) For discussions in SLA, see, e.g. Gasser (1990), Sokolik (1990), and Jensen and Ulbæk (1994)

<sup>8</sup> For this reason, Stauble and Larsen-Freeman (1977) suggested the use of variable rules as descriptive devices Although still product-oriented (as opposed to process), variable rules attempt to portray the changing nature of interlanguage over time

<sup>9</sup> I refer here to 'grammars', but I mean these concepts to apply to the acquisition of any component of the target language system Nevertheless, it is well known that most of the evidence has been adduced in the area of morphosyntax

<sup>10</sup> And, as Lewis (1993: 58) puts it, the notion of a definable target is an idealization anyway as there is no such thing as a homogenous speech community

<sup>11</sup> This is not to say, of course, that learners cannot make progress in bringing their IL

grammars more in alignment with that of native speakers Presumably, the rate of learning and the rate at which the target language is developing differ

<sup>12</sup> Presumably, it is because of these factors that although both L1 and L2 acquisition are complex, dynamic processes, they do not play out in the same way

<sup>13</sup> Except perhaps for the absolute impact of age on pronunciation ability Others of these may very well be determining factors at the level of the individual, and many individuals will be able to explain their progress or lack thereof in terms of one or more of these variables

<sup>14</sup> The common occurrence of overgeneralization has always been cited as evidence for a rule-formation view of SLA It should be noted, however, that the connectionist models have yielded very similar typical developmental patterns for English past tense formation without the need to build in 'rules' (Rumelhart and McClelland 1986) The networks control what looks like rule-governed behavior, but which is simply a reflection of the connections formed on the basis of the relative strengths of various patterns in the input Such findings make me optimistic that the observed frequency effect for the morpheme accuracy order (Larsen-Freeman 1976) might be simulated in a similar manner, and that connectionist models will provide a means to accommodate the fact that much of our fluency in spoken language is due to the thousands of prefabricated routines and collocations we control (Pawley and Syder 1983, Nattinger and DeCarrico 1992, Weinert 1995)

<sup>15</sup> This would seem to be similar to Piaget's central constructive mechanism, 'equilibration', however, as it is used in the Piagetian sense, it is the mechanism by which the child moves from one state of equilibrium to the next (Ginsburg and Oppen 1969) By way of contrast, the perspective adopted for this article is that there is no state of equilibrium possible The whole system is constantly in flux and chaotic

<sup>16</sup> Taylor (personal communication) has suggested the analogy between fixed point attractors and fossilization I am not sure what in chaos theory would account for why a dynamic system stops evolving and becomes fixed Perhaps it is that the sociopsychological factors in SLA transform the open system to a closed one—which I realize is not an explanation at all

<sup>17</sup> Recall that this is the same question that drives complexity science

<sup>18</sup> Observing that social interaction is necessary in order for the system to develop appears to be similar to Vygotsky's (1981) and Luria's (1973) position, although it seems to me that they would claim that it is social interaction alone, or at least primarily, that drives development and that the other half of the partnership—pattern formation of the sort Mohanan is describing—would not be necessary Of course, unlike Vygotsky and Luria, here we are concerned with language development exclusively and it may be that with language development, pattern formation has a greater role to play

<sup>19</sup> It is possible, for example, for a learner to use a more sophisticated form at time 2, compared with time 1, and not receive credit for having learned anything since the form at time 2 remains non-target-like

<sup>20</sup> I think it has implications for language teaching as well, but these are beyond the scope of this paper

<sup>21</sup> For example, Tarone (1990) sees a place for both rationalist and variationist views of SLA

<sup>22</sup> Indeed, I am certain that my interest in chaos/complexity theory is in part attributable to aesthetics (Schumann 1982)

<sup>23</sup> To teaching, as well, I hope I am constantly reminding students, audiences, and myself that teaching does not cause learning

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