

# The Implication of Chaos/Complexity Theory into Second Language Acquisition

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## **Abstract**

With the advances in Quantum physics and meteorology, science has moved towards more uncertainty and unpredictability (Larsen-Freeman, 2002) [12]. This has resulted in the emergence of Chaos/Complexity Science (Valle, 2000) [20], or Theory (Larsen-Freeman, 1997) [11], and Dynamic System Theory (De Bot, Lowie, & Verspoor, 2007) [3]. As Larsen-Freeman (1997) [11] states the name of chaos/complexity science is paradoxical terminology in that the word science means order as well as complexity but in Ch/C this complexity is achieved through chaotic situation. In science we are searching for cause and effect connection while in Ch/C such a connection is not that much straightforward.

Efforts have been invested to apply the concept into Second Language Acquisition (SLA) (Larsen-Freeman, 1997) [11] due to incommensurable issues in SLA Larsen-Freeman (1997) [11], especially, introduced the concept into SLA in detail, however, we think more works and speculations on the topic are required on all aspects which are related to SLA. To this end, this article is a critical review of the implication of Chaos/Complexity theory into SLA from three perspectives: the Nature of Language Complexity, SLA Incommensurable Theories, and the Complex Nature of Classroom.

**Keywords:** chaos, complexity, SLA

## **1. Introduction**

The 21<sup>st</sup> century is the time of uncertainty and unpredictability. The former is introduced in Quantum physics and the latter in meteorology. The result of such thorny situation is the emergence of new science which is called as Chaos and Complexity Science (Ch/C) or Theory. (Ch/C) and Dynamic System Theory (DST) are the most recent and conceptually related theories in all disciplinary areas and rooted in mathematics. Modaresi (2010, personal communication) finds five different definitions for chaotic issues from SLA perspective. Accordingly, Chaos is science not state, is randomness emerged out of complexity, is mathematical term to explain an unpredictable behavior which is not random, and is unpredictable behavior in a nonlinear system. To Baranger (2002) [1], “chaos is a purely mathematical concept”, and as mathematics is a universal logic, the concept he believes to be a universal concept which can be applied to any other disciplinary areas. By the same token, DST asserts that every equation with “two degrees of freedom turns into a complex system due to its interconnection with other system” (De Bot, Lowie, & Verspoor, 2007, p.7) [3].

Ch/C dated back to 1960s, when Lorenz, a meteorologist, noticed that a very small difference could lead to large changes in the weather (Valle, 2000) [20]. Later on, the concept has

been applied to other areas of study like physics, mathematics, chemistry, even sports. In this respect, McAndrew (1997) [16] believes that no one can find any reality without chaos.

In statistics, Chaos is usually referred to noise. It is part of error of measurement in language testing. In any statistical analysis, researchers try to avoid errors and usually omit items with high index of standard error of measurement. This is usually done to reach a “purely true score” of the ability under the study. The concept of generalizability refers to the same wish for observing predictability of the result on any kinds of measurement. This is the sign for “ignoring chaos or dismissing it as “noise” in an otherwise well-defined system, even though chaos is the rule much more than the exception” (p. 37). From the Ch/C perspective the universe under the study is not linear, predictable, nor is it studied in a reductionist way (Harshbarger, 2007 [6]; Kymes, 2007 [10]; Mitchener & Nowak, 2004) [17]. McAndrew (1997) [16] assigns three features to chaos

- a. “Chaos is characterized by a sensitive dependence on initial conditions or what has become known as the butterfly effect
- b. Chaotic system is aperiodic or never undergoes a regular repetition of values. No repeat system,
- c. strange attractors (attract and repel): attractor means no repeat characteristic. (p. 39)”

Ch/C Science focuses on complex, dynamic, nonlinear systems. It is not the science of fixed entity but dynamic; it is about process than state. Ch/C studies the whole through interactions of its components. The result of behavior is not predictable. According to Baranger (2002) [1], any system whose “configuration is capable of changing with time is known as a dynamic system” (p. 7). The result of such interactions is the emergence of behavior whose physical manifestation is highly dependent on the complexity of the interaction.

Ch/C, this way, is deterministic and non-periodic. It is deterministic because the initial change would surely lead to great change and chaotic behavior is not random. It is non-periodic in the sense that nothing would be considered as repetition even if they look alike. This is because that a closer look at any system would lead us to the understanding of movement in that system. Therefore, CC is sensitive to the initial condition. The next feature of CC is unpredictability. Because CC is unstable, a periodic and sensitive to initial conditions, it is unpredictable as well. Moreover, CC is systematic; this is the complexity part of the CC. Also, there is strange attractor in CC which refers to whatever happens seems to be new to the system. A final feature of CC is iteration and feedback. This means that the output in one system can be used as input in the same system.

The complex system is open to import energy from the environment. This way new order can emerge from disorders. The system is dynamic and moves through space and time. It follows attractor which is a state or pattern that the system attracted to. The attractor is strange because it never crosses itself. And finally, Ch/C is nonlinear in that the effect is not proportional to the cause; a minor change can cause a great change in the whole system.

Chaotic feature of Ch/C system denotes to randomness due to the complex structure of the system (Larsen-Freeman, 1997 [11], 2002 [12], 2007 [13], 2008 [14]) in the way that the system cannot be reduced into simpler parts (the concept of Fractal).

The second concept internal to Ch/C is “Complexity. In a complex system there are numerous independent elements that are continuously interacting with each other thereby simultaneously organizing and reorganizing themselves into a more multifaceted system. A complex system has the following features:

- ✓ A large number of similar but independent elements.
- ✓ Constant movement and responses to other agents.
- ✓ Adaptiveness to ensure survival.
- ✓ Self-organization in which order in the system forms spontaneously.
- ✓ Local rules that apply to each agent.
- ✓ Progression to make the system more sophisticated and larger.
- ✓ Unpredictability.
- ✓ Subtractivity.

In complex system we do not see the progression in the form of additivity but complex systems can evolve to a state of self organized in the way that behavior is set between order and disorder.

## **2. The Concept of Deterrence in CC**

Valle (2000) [20] discussed the concept of deterrence within Ch/C Theory. Accordingly, the more parameter in the operation, the more unstable the system will be. Deterrence is also nonlinear. This means that if we deter something to happen, something else will happen. Deterrence is chaotic in the sense that it is unpredictable. Also, deterrence is a function of will and capability. It is the function of capability because is relative to the capability of one's potential adversaries. Also will is not similar to the actual will that is perceived by one. This means that the more deterred we are, the less likely we are deterred in our enemy.

## **3. Chaos/Complexity in SLA**

For the first time, Larsen-Freeman (1997) [11] brought the concept of Ch/C into explaining the thorny issues we face in SLA. Ch/C can be discussed in SLA from several perspectives. The first maintains the idea that language is a dynamic system (De Bot, Lowie, & Verspoor, 2007 [3]; Paiva [18]). The second holds the idea that SLA is a turmoil area of study in which there are many incommensurable theories competing with each other (Larsen-Freeman, 2007 [13], 2008 [14]; Harshbarger, 2007 [6]). And finally, the third is related to the instructed SLA where many unpredictable factors come into relation with each other dynamically (Hadidi, 2008 [5]; Kymes, 2007 [10]).

There are some metaphors to understand Ch/C theory. One metaphor is dynamic system. By dynamicity, as was mentioned earlier, we mean a nonlinear system in which everything is interconnected. Also the system is dynamic in the sense that it changes by time. Another feature of the system is complexity in the sense that it has a large number of components or agents which are connected to each other in one way. Therefore, a single effect on one part of this system can lead to a great change in whole system.

The metaphor of butterfly in Ch/C indicates the importance of minor changes which lead to great changes at the end. Butterfly effect, which was originally mentioned in meteorology, means that a single and unimportant flying of butterfly may lead to a hurricane in one part of the world; this happens because of interconnectedness of the world into a dynamic system. Another metaphor in Ch/C is camel back effect which refers to a story in which a man put a lot of loads on his camel but his camel stood up and started to move. Later, he remembered he had a feather and when he put it on his camel's back, the camel collapsed. This story, again, referred to this fact that many other things should be involved so that a tiny change would result in great changes.

As was mentioned earlier, Ch/C is chaotic, unpredictable, and sensitive to initial conditions. It is chaotic because it refers simply to the period of complete randomness and this randomness is unpredictable and irregular in the sense that the time of its occurrence is not known to us. Also Ch/C is open, self-organized, feedback sensitive, and adaptive. It is open in the sense that the entire universe increases in entropy which is a measure of the number of arbitrary ways of arranging a system (measure of disorder). Through this unpredictability, a highly organized stated appears suddenly. And feedback sensitive means that the ending point in a system is the starting point in another system. According to McAndrew (1997) [16], "something is complex if a great many independent agents are interacting with each other in many ways, the richness of these interactions allowing the system as a whole to undergo spontaneous self-organization" (p. 39).

Also, Ch/C is strange attractors and fractal shape (Larsen-Freeman, 2002 [12], 2008 [14]). According to Baranger (2002) [1], an object is chaotic in space in the sense that it is called fractal. Fractal is a geometric figure that does not become simpler when one analyzes it into smaller parts. Also strange attractor is one of the features of Ch/C in the sense that the system can repeat itself and each occurrence is not the same as what occurred before.

Therefore, the features of CC can be summarized as below:

- ✓ Dynamic: it changes over time even if they look alike
- ✓ A-periodic and unstable: it does not repeat itself.
- ✓ Complex but having simple causes.
- ✓ Non-linear: sensitive to initial conditions (the output is not proportionate to the input: synergistic reaction).
- ✓ Deterministic: it is not random.
- ✓ It is instable, a-periodic, sensitive to initial conditions and therefore unpredictable.
- ✓ Iteration/feedback: the output of the system is used as the input in the next calculation.

#### **4. Chaos /Complexity and Language**

To Larson-Freeman (1997 [11], 2008 [14]), language is a complex nonlinear system. It is dynamic because its process involve an active process also dynamic equates growth and change. It is chaotic because there is no one to one correspondence between form and function. Also it is dynamic in the sense that there is no difference between the current use and change or growth of language; they are the same. Messages emerge as the result of speaker and listener's collaborative effort. Fractality of language results in the existence of infinite number of behavior within a finite system.

Mitchener and Nowak (2004) [17] also believe that "human language is a complex communication system with unlimited expressibility" (p. 701). Accordingly, speakers have a subconscious internal representation of a grammar, which enables them to generate and understand sentences of their language. Children build their internal "grammar by generalizing from linguistic data they receive from their speech community" (p. 701).

Language change is unpredictable and highly sensitive to perturbations SLA with lots of occurrence and reoccurrence of new theories can only be explained within chaos complexity theory. Hadidi Tamjid (2008) [5] believes that complexity is a two-folded concept. One the one hand, it is related to the fact that "language is a collection of static units but their use in actual speech involves an active process" (p. 11). On the other hand, language is a phenomenon which faces continually growth and change.

#### **5. Chaos/Complexity and SLA Theories**

Larsen-Freeman (1997 [11], 2002 [12], and 2008 [14]) believes that SLA can be explained within Ch/C theory. The SLA process seems to be very complex. There are many theories, sub-theories, models and hypotheses have been proposed in SLA which explains the nature of language leaning. These theories are most of the time incommensurable in the sense that one theory rejects the other one. These debates go around the centrality of cognition, environment, affective factors, social factors and sociocultural factors in language learning or acquisition. However, they do not reach the agreement on what of and how of second language learning. These views, sometimes, are competing in the sense that one rejects the other one. For example, Vygotsky's perception of learning is different from Chomsky's. Elsewhere, Paiva [18] shows the internal connectedness of different variables central to the process of SLA. To him, interlanguage works as a strange attractor which is highly sensitive to initial conditions. He, also through think aloud analysis, analyzes different strategies learners use to learn language. Each of these strategies can be attributed to one of the theories of SLA.

#### **6. Chaos/Complexity and Language Teaching**

In some, all features of Ch/C can be applied to SLA in the sense that SLA is nonlinear, self-organized, and chaotic. In SLA there are strange attractors which are constrained by first language. It is sensitive to feedback as there is no possible learning even without negative evidence.

To Kymes (2007) [10], schooling is a complex and chaotic system which "can be better understood through principles of chaos and complexity theory such as self-organization, strange attractors, and emergence" (p. 328). Kelly (1996, as cited in Finch, 2001) [4] classified variables

involving in any classroom into macro and micro types. Accordingly, Macro skills are initiating (introducing the topic), goal-setting, guiding, modeling, supporting, giving feedback, evaluating, linking, and concluding. Also, micro skills refer to attending, restating, paraphrasing, summarizing, questioning, interpreting, reflecting feelings, empathizing, and confronting. While, from linear perspectives, these macro and macro variables are sequentially related to each other, from Ch/C they are interconnected and nonlinear. Therefore, in Ch/C research, we need to remain flexible and keep as many options open as possible.

In Ch/C educational success is defined from two perspectives (Larsen-Freeman, 1997) [11]. The first one is though acquisition metaphor which defined success of learning as the result of an acquisition of something which is set a priori to the sequence of learning. The second one is the participation metaphor which pays attention to activities. The latter view sees leaning a language as a process of becoming the member of one community so the ability to communicate is important. While acquisition metaphor pays attention to individual mind and inside of mind, the participant metaphor focuses on “evolving bond” between individuals.

### **7. Dynamic System Theory (DST)**

A related concept to Chaos/complexity theory is Dynamic System Theory (DST). DST, too, was originated from mathematics in the sense that every equation with “coupled variables” and with only “two degrees of freedom” turns into a complex system due to its interconnection with other systems (De Bot, Lowie, & Verspoor, 2007) [3]. When it comes to learning theories, such interconnectedness is vivid in most connectionist theories where a single change in the system will affect all other parts of the system.

There are several key points in DST; DST is nested in the sense that there is no single system in the universe and every system is a subpart of another system (De Bot, Lowie, & Verspoor, 2007) [3]. This ever-changing attribute of the system is called “attractor state” (Larsen-Freeman, 1997 [11], 2002 [12], 2007 [13]; Valle, 2000 [20]) which means that any occurrence is generically new and should be approach pragmatically. As De Both, Lowie, & Verspoor (2007) [3] state, the “systems are constantly in flow” which means that the system is constantly changing due to its interaction “with environment” and self “through internal self-reorganization” (p. 8). In this respect, they believe that in DST complexity and therefore creativity emerges from the iterations.

Mohan (1992 as cited in De Both, Lowie, & Verspoor, 2007) [3] relates a dynamic perspective to “UG by viewing universal principles as Fields of attraction and argues that a DST perspective can explain the emergence of complexity in phonological development” (p. 10). To Larsen-Freeman (2007) [11], the two perspectives are complementary and could exist side by side with their own research traditions and communities. A DST approach to communication is incompatible with an information processing model and even through it does not necessarily reject innate principles it does not need specifically linguistic principles to account for the creativity in language use. From a DST perspective, language acquisition emerges through interaction with other human beings within a social context.

### **8. Is Chaos Complexity the Answer to Unresolved Issues?**

Many issues are open to question in SLA, language testing and applied linguistics. In SLA and Applied Linguistics, what we are facing with is the plurality of theories (Jordan, 2004) [8]. According to Bretta (1991) [2], SLA like other human science is in crisis for its multiple rival theories. In other words, SLA seems not to conform to a single paradigm unless we accept that such competition is part of a complex system. In language testing, we are facing with paradox of validity and generalizability (McNamara & Roever, 2006) [15]. In language teaching, the movement against specific (Kumaravadivelu, 1994) [9] method indicates the fact that no single method would possibly solve the problems of language learning in classrooms. The question is whether we are facing with inconsistencies in language teaching and language related science or what we observe is the complexity, and the chaotic situation is part of this complex system.

## 9. Conclusion

Like any other revolution, Ch/C is a reaction to incapability of isolationist methodology of doing research in accounting for all the anomalies and exceptions those research enquiries came up with. Ch/C research, instead, focuses on synthesizing the emerged whole through studying the idiosyncratic interaction. In dynamic system, an output of one process is the input of another process. In this respect, De Bot et al (2007) [3] state

The major property of a dynamic system is change over time. Through iteration of simple procedures that are applied over and over again with the output of the preceding iteration as the input of the next, complexity in language emerges. (p. 19)

Many lessons can be drawn from this perspective. First, CC is not a reductionist view and moves us towards holism; this means that to understand a behavior we cannot go through parts. Second, it moves us away from easy distinction or false dichotomies. The complex system is characterized by a dynamic attractor and fractal pattern. We should pay attention to interconnections. Also, CC sees any system as open which is not homeostatic but complex.

In sum, within this system, the following features can be investigated:

- Mechanism of acquisition: it is explained through the concept of entropy which explains the output complexity is beyond the complexity of the input. Also, the concept of adaptation (interlanguage is adapted through exposing to different levels of input like pidginization and denativization and the like) and morphogenesis.
- Definition of learning: strange attractors which means grammar learning changes continually. This is mostly related to what Bakhtin (as cited in Holquist, 1990) [7] has referred to heteroglossia of language.
- The stability and instability of interlanguage: there is stability when there is no change over time but there is instability in Tarone's [2007] [19] sense of variability
- Individual differences: the more variable we find we come to the point that we cannot find the main effect in language learning success
- Effect of instruction: in complex nonlinear system, the behavior of the system depends on change in a small part.

In conclusion, we might say that the social participation view of SLA is supported by CC although psychological perspective should not be abandoned. CC encourages us to think in relational term.

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