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A Dynamical System Approach to Research in Second Language Acquisition

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Abstract

Epistemologically speaking, second language acquisition research (SLAR) might be reconsidered from a complex dynamical system view with interconnected aspects in the ecosystem of language acquisition. The present paper attempts to introduce the tenets of complex system theory and its application in SLAR. It has been suggested that the present dominant traditions in language acquisition research are too simplistic to delve into the nature of language acquisition. The belief is that the Newtonian conceptualization of SLA research cannot be comprehensive to deal with the complexities of language acquisition research. So the suggested definition for SLA research in the present paper is a complex dynamical nonlinear open adaptive system of inquiry to find probable solutions to problems.

Keywords: second language acquisition research; complex system theory; dynamical; emergent; reductive.

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Introduction

From an ontological perspective, research in education in general and second language acquisition in particular has witnessed fluctuations galore. In the milieu of second language acquisition (SLA), the definition of *research* in applied linguistics, as with many other terms, is not clear-cut, and the field is replete with terminology confusion. Brown (1988) classifies research into two broad categories as secondary and primary research, each of which subcategorized into other types. Van Lier (1988) considers educational research in terms of intervention and selectivity axes. Grotjahn (1988) classifies research in terms of methods of data collection, data types, and data analysis procedures. To Larsen-Freeman and Long (1991), research could be taken into account cross-sectional or longitudinal time orientation. Reichardt and Cook (1979) sum up research types into qualitative and quantitative paradigms where the former supports a particularistic perspective and the latter a holistic one. More specifically, Dornyei (2007) in his brief historical overview of QUAN-QAUL research paradigms, quotes that quantitative research is closely associated with numerical values and standardized procedures and so a scientific method whereas qualitative paradigm is believed to be "open and fluid" and "without preconceived hypotheses". Mackey and Gass (2005) equate quantitative research with experimental design and qualitative research with non-experimental paradigm. All these pave the way to the point that *research is a complex system* which needs to be interpreted in terms of the features of a complex system.

This article is intended to briefly grapple with issues about second language acquisition research (SLAR) through the lens of recent advances in dynamical complex system theory. The rationale in the succinct paper is that research is not a concept to easily arrive at, and we hope this perspective may help put forward questions about research differently and more usefully. Using Cummins (1983) classification of theories into property and transition theories, and resorting to Larsen-Freeman's (2008) characterization of complex systems in applied linguistics, to me, second language acquisition research might be redefined as a *complex dynamical nonlinear open adaptive system of inquiry to find probable solutions to problems.*

Complex system theory: The background

Complexity theory is originating in the natural sciences and applied in the human sciences. Complexity theory makes an attempt to expound the way order comes out of chaos in systems. Regarding living systems, the theory explains the creation of complex adaptive systems and their existence. Historically speaking, the origin of complex system theory dates back probably to the meteorologist Edward Lorenz seminal experiment in 1961 when he had managed to create a skeleton of a weather system from a handful of differential equations. Applying computer simulation, he maintained a perpetual simulation that would produce an output of a day's progress in the simulation every minute as a line of text on a roll of paper. Lorenz examined the way an air current would rise and fall while being heated by the sun. His computer contained the mathematical equations which governed the flow of the air currents. Because of the deterministic nature of computer code, Lorenz predicted that by feeding the same initial values, he would obtain exactly the same result when he ran the program. However, Lorenz found that when the same initial values were given, he came into an exactly different result each time. By closer examination, it was revealed that he was not truly imputing the same initial values each time; initial values were a little bit different from each other. The differences were not noticed since they were unbelievably small, microscopic, and insignificant by usual standards. The simulation pattern revealed that nothing ever happened the same way twice, but there was an underlying order. He noticed that a small change in initial conditions can drastically change the long-term behavior of a system (known as Lorenz attractor).

Lorenz famous paper entitled "Predictability: Does the flap of the butterfly's wings in Brazil set off a tornado in Texas?" in 1972 is associated with *butterfly effect* or *chaos theory*. It came to be known that even the smallest imaginable difference between two sets of initial conditions would result in a great difference (Gleick, 2008; Stewart, 2002).

In addition, some Nobel laureates including Ilya Prigogine in chemistry, Kenneth Arrow in economics, and Philip Anderson and

Murray Gell-Mann in physics are among the advocates of complexity theory. The potential of complex systems is so great since it deals with real systems in the real word, say, transportation system, human immune system, forest, educational systems, weather, and SLAR indeed. As Gell-Mann (1994) states, although complex system theory has originated in the natural sciences, it has exciting and useful contributions to the social and behavioral sciences, and even matters of policy for human society.

The chemist Ilya Prigogine coined the term dissipative system to clarify an inherent process quintessential in complex systems. His proposition is that a dissipative system takes in energy from outside of itself and self-organizes its pattern. In fact, a dissipative system is open to the external context and regulates itself to create order. As Larsen-Freeman (2008) quotes him, "the study of dissipative systems focuses on the interplay between structure, on the one hand, and change (or dissipation) on the other" (p. 3).

Holland (1995), a biologist and the father of genetic algorithms, enumerates four properties (aggregation, nonlinearity, flows, and diversity) and three mechanisms (tagging, internal models, and building blocks) for each complex adaptive system. Aggregation implies the way complex systems behave. Complex behaviors emerge as the result of interactions of less complex agents. To him, for example, an ant has a stereotypical behavior and usually dies when in non-normal situations; nevertheless, the ant nest is extremely adaptive and can generally survive abnormal conditions. In nonlinearity, the behavior of the whole cannot be reduced to the sum of the parts. According to nonlinearity, the behavior of complex systems cannot be taken by the behaviors of individual members. For instance, a watch, which is a complicated but not complex system, can be understood based on the interactions of the parts as it is a linear system. The third feature is flows which refer to the movements of resources among agents via connectors that change according to the system. For example, the connectors in a food transportation system are various vehicles, the resources flowing are the different foods, and the agents are farmers and grocery stores. The last feature is diversity. One can see diversity in educational systems where different types of teachers, staff members, and students interact (Holland, 1995).

Complex systems involving chaos are against determinism in philosophy. Determinism is the belief that every event is the inevitable result of preceding events, and thus every event can be completely predicted in advance. Determinism in philosophy dates back to ancient Greece, but its application in science traces back to 1500 A.D. with the idea that a cause-and-effect rule governs all motions. At the beginning of the 17th century, Francis Bacon contributed to the so-called scientific revolution by his empirical method and his emphasis on reliable knowledge. Bacon suggested that empirical observation and formal experiments are the real business of science. Newton's general law of gravitation was published in 1687 which put forward a coherent explanation of the movements of the planets (Jordan, 2004). Accordingly, "given the *initial* conditions (the position and velocity of each body) and the acting forces, the entire future history of that system is determined uniquely" (Retrieved from http://www.skidmore.edu/academics/lsi/arcadia/newton.html).

In contrast, chaos could be considered as a superseder for the Newtonian metaphor of the clockwork predictability, as pointed out by Waldrop (1992). Instead of explaining the universe as a gigantic clock which is governed by simple rules, chaos theory metaphor can be described as "a kaleidoscope: the world is a matter of patterns that change, that partly repeat, but never quite repeat, that are always new and different" (p. 330).

In the 20th century, mechanical determinism was attacked and broke down gradually. The idea that quantum mechanics is based on the principle of uncertainty rejected the determinism at a microscopic level; similarly, the butterfly effect resulted in the denial of the determinism at a macroscopic level. Based on the Copenhagen paradigm of quantum mechanics, a microscopic system is considered as an uncertain wave motion that gets certain merely when a recognizing subject interferes with the object rather than the object is basically determinate. An issue of great interest in quantum mechanics is *the principle of superposition*. According to this principle, "quantum mechanics requires that a system exist in a range of possible states…until a measurement is made, at which point one of those states takes on a definite reality" (Lindley, 1997, p.18). Hence, the core of the superposition principle is that an organism exists in more than one state at any given time. To Niels Bohr, the criterion for everything to be real is its observability. At the same time, he, nevertheless, stated that the act of measurement constrains a thing to a single possibility. Both of these observations are embodied in the principle of superposition.

Complexity theory and SLA

With the spread of complex system theory in physics, mathematics, and biology, in the last decade the enthusiasm for its modeling to SLA context in general and second language acquisition research in particular has caught the attention of some researchers. It appears the time is ripe for SLA to follow the empirically based new trend in science and get divorced from absolutely Newotnian camp of causative reality and its reductionist positivistic linear tenets. Some scholars have felt the new conceptualization of science and are heralds of changes in SLA. Consequently, a few articles and studies have been published using terminologies as complexity theory, chaos theory, dynamical system, and complex systems.

Complexity theory is scarcely dealt with in the literature of SLA. Two seminal articles by Larsen-Freeman (1997) and van Lier (1997) brought complexity theory into the realm of applied linguistics. Larsen-Freeman's influential article "Chaos/Complexity Science and Second Language Acquisition" in *Applied Linguistics* in 1997 introduced the main developments of physical sciences contributing to the recent developments in academia. She has enumerated the main features of complex systems: dynamic, complex, nonlinear, chaotic, unpredictable, sensitive to initial conditions, open, adaptive, and self-organizing. She also compares complex systems and language in terms of dynamism and finds numerous commonalities including the fact that languages grow and change. She draws readers' attention to the applicability of complex system theory to interlanguage systems of language learners. Furthermore, to Van Lier (1997), it is essential to consider second language classroom context as a complex adaptive system in which the details are all significant. He further maintains that it is not feasible to search for cause-effect relations in SLA.

Following the seminal works by Larsen-Freeman and some other researchers to introduce Gleick's (1987) *Chaos: Towards a New Kind of Science* and Waldrop's (1992) *Complexity: The Emerging Science at the Edge of Order and Chaos*, today, it appears that complex system theory has found its way into recent discussions in SLA and applied linguistics and researchers in the field believe in its role in interlanguage systems. Later, Bates and Thelen (2003) relates connectionist theories of mind to complex system theory. Larsen-Freeman (2000) explains language as a dynamic system which is composed of numerous components including syntax, semantics, phonology, morphology, and so forth interacting in non-linear and unpredictable ways. Larsen-Freeman coined the term "grammaring" to describe this dynamic nature of language. Cameron (2003) links the complex system theory to discourse and applies the term "attractor" to explain discoursal features in language use. Verspoor, Lowie, and van Dijk (2008) show that examining intra-individual variability in SLA can provide insight into the dynamics of second language learners. In their study, using Thelen and Smith's (1994) and van Geert's (1994) dynamic systems theory paradigm and concepts from microgenetic variability researches in psychology, they investigated SLA in a rapid development time period applying advanced visualization techniques. A case study of a learner displays a general increase over time for the correlates under study; however, the development is nonlinear, which reveals moments of progress and regress. The case study sheds light as well on dynamic interaction of subsystems. In another article, van Geert (2008), introduces the basic tenets of dynamic system theory and explains concepts such as time evolution, evolution term, self-organization, and attractor. Furthermore, the applications of these concepts in first and second language acquisition are discussed. The article also expounds the steps necessary to be taken in modeling dynamic system theory in second language learning. de Bot (2008), focuses on the development of SLA from the perspective of dynamic system theory with a focus on development over time. Numerous examples and applications of dynamic system theory in SLA are given. The author also offers some possible lines of dynamic-system-theory based research agendas. Plaza-Pust (2008) examines Universal Grammar based on dynamic system theory and proposes a dynamic approach to the development of grammars. He attributes the observed nonlinear behavior to a complex information flow by internal and external feedback processes. He further argues that changes in grammars are because of the amplification of new information leading to system-internal conflicts.

Complex system theory and SLA research

Complexity as a concept in science is not totally new (Sardar & Abrams, 1999); however, we observe the incarnation of the concept in natural sciences first and today its emergence in second language acquisition research**.** It might be argued that the advent of complexity in second language acquisition research implies the "shift of paradigm", to use Thomas Kuhn's terminology in the philosophy of science (as cited in Jordan, 2004; see also Watson -Gegeo, 2004 for paradigm shift in human and social sciences). Like language, language acquisition research is a multifaceted phenomenon involving numerous endogenous and exogenous variables. In the past decades, second language acquisition is researched from different perspectives: cognitive, affective, cultural, social, political, ideological, and so forth. Nevertheless, the attempts made by majority of researchers in the field have centered around reductionism and separationist linear conceptualizations in research. If language acquisition is viewed from an ecological approach in which the affordances in the ecosystem of language acquisition are all taken into account, complexity theory finds its way into SLA research paradigms. Therefore, van Lier's (2004) "deep ecology" conceptualization might be borrowed to explain the interrelatedness and complexity of all processes involved in second language acquisition research.

In the following sections, the intention is to argue for a complex system theory approach to research in second language acquisition with a critique of the so-called standard scientific research. It appears that complex system theory attributes (dynamic, complex, nonlinear, chaotic, self-organizing, unpredictable, and sensitive to initial conditions) challenges the basic tenets of established practices in experimental research paradigms. For the purpose of our discussion, the elaborations by Larsen-Freeman and Cameron (2008) concerning the features of a complex system appear plausible and helpful.

SLAR as a system, a complex system

A system is defined as a set of components that work together in a certain way to produce some overall state (Larsen-Freeman & Cameron, 2008). We need to differentiate a system from a set since belonging to a system has an impact upon the features of the components. For instance, a classroom is a system in which several components interact: teacher and his/her characteristics, students and their characteristics, tasks and activities, lessons, teaching materials, mnemonics, and etc. The quintessential feature of this classroom system is that the components of the system affect each other, say, teacher's method is influenced by students' characteristics and classroom atmosphere. Systems could be simple or complex. A simple system consists of limited number of components with predictable patterns of behavior. A traffic light system is a simple system of typically three options (in Iran): green, amber, and red. The pattern of traffic light as a simple system is unchangeable and therefore a predictable sequence is followed: motorists know that an amber light will be followed by a red one which means to stop. A complex system, in contrast, involves a large number of elements which interact in different and changing ways. The elements of a complex system are technically called component *agents* and component *elements*. Agents are animate beings in a system whereas elements are inanimate aspects of a system. In the classroom metaphor, agents are teachers and pupils, and elements are facilities, equipments, and the board to list a few. The point here is that the ecosystem of a complex system is *heterogeneous* in the sense that it contains miscellaneous agents, elements, and processes, processes could also be part of components. So, it could be claimed that in a complex system one can find both entities and processes.

Considering the above mentioned characteristics of a complex system, SLAR could be supposed as a complex system. It is a *system* inasmuch as it is produced by a host of components to bring up some overall state, here a solution to a problem. In addition, SLAR is necessarily a *complex* system since it involves heterogeneous agents (researcher and participants) and elements (treatment, placebo, data, instructional materials, pre- and post-tests to name a few). In addition, the process component contributes to the complexity of the SLAR system. Van Lier (2000) takes an ecological approach to language learning and emphasizes conglomeration of cognitive, social, and cultural aspects and their interactions in learning atmosphere. The likely problem with the so-called scientific research paradigms in language learning is that the ecology of research is limited to merely cognitive processes; that is, learning is the result of computational processes in the brain. Bronfenbrenner (1994) proposes a bioecological model of hierarchically nested ecosystems and a research methodology for studying language acquisition that contains the notions of person, process, context, time, and outcome (cited in van Lier, 2000). So from a complex system SLAR, to arrive at meaningful and useful interpretations of research results, researchers need to consider the complexity of SLAR in terms of its agents, components, and elements.

SLA research as a dynamic process

A system is defined as dynamic, i.e. a set of variables that interact over time (de Bot, Lowie, & Verspoor, 2007). To apply the conceptualization of complex system theory, research in second language acquisition is dynamic in the sense that it is composed of a multitude of agents, elements, and variables. In other words, SLAR might be assumed as a network of agents who are acting in parallel, competing, cooperating, and responding to the actions of other agents, elements which are interacting in the ecosystem of research milieu, and variables which are both manipulated and uncontrolled. The agents and elements are indispensably interconnected and interdependent and act upon each other over time contributing to the unpredictability and dynamism of the SLA research practice.

Being so, based on the complex system theory, taking the agents, elements, and variables action throughout research into account, the Newtonian separationist simple causal explanation appears implausible. An underlying assumption in the so-called scientific research is that in second language acquisition research there exists a clear beginning and end state. On the contrary, second language research is dynamic in the sense that it constantly changes overtime.

Standard research is reductive; Complex system research is emergent

In the previous section, it was argued that SLAR is complex since it involves heterogeneous agents, elements, and processes. However, it should be noticed that, as Larsen-Freeman and Cameron (2008) state, complex does not mean complicated. What makes a system complex is not merely the existence of a large number of elements. In other words, the diversity of components does not make a system complex. In fact, the behavior of a complex system "emerges from the *interactions* [emphasis is mine] of its components" (p. 2). The interaction of elements in a complex system leads to the emergence of new behavior and self-organization. Because of the interactions among the elements, they act in response to the feedback they receive which itself leads to change and adaptation. That is the reason why sometimes complex systems are also called adaptive systems.

Standard scientific research is based on reductionism in the philosophy of science. As van Lier (2000) states, the scientific perspective dominating Western civilization since the days of Galileo and Descartes has advocated simplification and selection from the infinite variety of the real world. Jordan (2004) in a review of criteria for research and theory construction in SLA mentions the Occam's Razor principle as an essential standard for SLAR. Based on the principle, the theory which is constructed with the fewest types of entity is preferred for the reasons of economy. So the recommendation imposed by reductionism upon standard scientific research is the selection of the fewest possible number of components in a research context. In fact, reduction-based research simplifies a system in a process called *idealization*. The concept dates back to ancient times when Plato considered meaning as an idealization which was already known to the mind independent of the world experience that awakened it (Weisler & Milekic, 2000). Probably, it might be the reason why Chomsky mentions "idealized speaker" in his theory of language acquisition. In addition, Chomsky's data consisted of idealized speech samples divorced from the localized impacts of specific dialects. Similarly, some recent research on second language sentence processing supports the syntax-based approach which considers comprehension process as the application of autonomous syntactic principles free from pragmatic, contextual, and real-world knowledge sources (Harrington, 2002).

Idealization and reductionism are quintessence of scientific experimental research in SLA. Following scientific vigor and flavor of natural sciences, experimental SLA researchers separate complex system from its real context and manipulate the research in a clinical milieu to investigate the targeted aspect. In other words, the so-called scientific research takes a snapshot of the language at an instant of time and idealizes away from contextual temporal factors and components contributing to the whole system.

Complex system SLAR, in contrast, believes in affordance and a bioecological perspective in second language research. Affordance, a term coined by the psychologist Gibson in 1979, deals with the interrelationship between an organism and particular features of its environment. Van Lier (2000) defines affordance as "a particular property of the environment that is relevant …to an active, perceiving organism in environment. An affordance affords further action (but does not cause or trigger it)" (p. 252). To clarify the affordance concept, he introduces the leaf metaphor in a jungle: the leaves is the same, and with fixed properties, but different organisms (a tree frog, an ant, a caterpillar, a spider, and a shaman) in a jungle perceive and act upon different properties of the leaf. In case of language acquisition, the environment is replete with language which offers opportunities for active participating learners. Similarly, a complex system SLAR supports an environment-based research that has the notions of person, process, context, time, and outcome. Affordance in SLAR is counter to dismantling subjects from the ecosystem they live in and investigating them in laboratory. It denotes the reciprocity between subjects in research and the environment of research. As Haugen (1972), the credited figure for introducing the ecology of language, proposes, we need not only the social and psychological states, but also the impact of environment on subjects engaged in research (cited in Hornberger, 2002).

So in complex system SLAR, we need to consider the whole ecology of language with all its complexity to arrive at more realistic interpretations of research results. In this regard, Larsen-Freeman and

Cameron (2008) deal with the methodological developments of second language research from the lens of complex system theory and propose that natural properties of complex systems demand changes in traditional considerations of the functions and roles of theory, hypothesis, data, and analysis. They maintain that context is not merely considered as a backdrop, but rather as a complex system itself which is related to other complex systems.

Conclusion

In the introductory paper, it was argued that second language acquisition research is such a complex phenomenon that simple cause-effect Newtonian research formulations cannot provide us with the true nature of language acquisition. Second language acquisition research is not a static phenomenon which might be preplanned to be conducted in predetermined processes. As Littlewood (2004) argues, what we have at the present time is middle-level rather than comprehensive theories of language learning. It appears that complex system theory has the potential to initiate a comprehensive theory regarding second language learning in general and SLAR in particular. In conformity with de Bot, Lowie, Thorne, and Verspoor's (2013) argumentation for a dynamical system as language learning, we might similarly assert that SLAR contains parts and factors which are changing over time, and the change happens through interaction with the research milieu and internal reorganization. Because of the interaction of the contributing factors over time, prediction of research results based on deterministic linearity rules is not possible. Second language acquisition is dynamic in this sense and it requires SLAR stakeholders be cautious concerning the interpretations from the results obtained.

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