A Brief Introduction and Overview of Complex Systems in Applied Linguistics

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Abstract

This overview paper is an attempt to provide a brief background and introduction to complex systems theory in applied linguistics as well as a review of the more recent work being done in the field. It is divided into two sections: developmental and theoretical backgrounds of complex systems theory, and a survey of research from a complexity perspective in applied linguistics. First, a short developmental background of complexity theory and how it entered applied linguistics is provided. A theoretical background of some of the key ideas in complex systems is then discussed. The second half of the paper begins with an overview of the past 20 years of complex systems work in applied linguistics which also touches on relevant work in cognitive development. Finally, current research being conducted in applied linguistics from a complexity approach is presented, followed by a proposal of future avenues of complexity research which may benefit the specific area of applied linguistics and the general understanding of human language.

Key Words: dynamic systems theory, complex systems, emergence, language development

Introduction

The twentieth century saw an explosion of technological and scientific progress unprecedented in human history; for the last 50 years, humanity has both grown and advanced exponentially, with communication and information more accessible than ever before through the propagation of computing and the internet. At the same time, through the sheer volume of work being produced as science and technology have evolved, the various fields have simultaneously become necessarily more specified and fragmented, where, were science a tree, one branch may have little idea what the rest of the branches were doing. Similarly, in the field of applied linguistics, theories and approaches of language acquisition in the past have been varied and at times conflicting. Do learners have Chomsky's (1965) built in language acquisition device (LAD)? Do they require Krashen's (1985) *i*+1 level of input in order to learn, or perhaps Schmidt's (1992) noticing? Does the brain operate more like a computer, storing and processing information accordingly (McLaughlin & Heredia, 1996)? And what aspect of a language learner (LL) is most appropriate for investigation, their physical brain (psycholinguistics), how they formulate and produce grammar (generative linguistics/syntax), how they conceive of and construct language (cognitive linguistics), how they form meaning (semantics), or the role of context (pragmatics) or society (sociolinguistics)?

Naturally, to single out only one of the above areas of study as necessary to understand language would be a futile effort; human beings and the societies in which we exist are interconnected, complex, and never static. In order to truly approach an understanding of human learning of any kind, especially language, which is so vital for almost every part of daily life, all aspects of human development must play a part. This begs the question of how to combine the social with the psychological, and everything in between, which is no simple feat. Fortunately, the previous century also saw a new concept making a name for itself. Complexity science, literally the study of systems with multiple interrelated parts, is an ever-growing approach being applied across the board: from ecology (Wu & David, 2002) and epidemiology (Galea, Riddle, & Kaplan, 2010) to economics (Westerhoff, 2003) and sociology (Hoffer, Bobashev, & Morris, 2009), and many more besides. Indeed, the past 20 years have seen a steadily increasing flurry of activity regarding this approach in the field of applied linguistics as well. Complexity theory may be exactly what applied linguistics needs in order to combine its various sub-disciplines in order to gain a more encompassing understanding of language and how it is acquired. Even if it seems a daunting task to purposefully embrace the complex, this conceptualization needs to be thoroughly investigated to determine its value for applied linguistics. While such investigation is beyond its capacity, this paper is meant to provide a review of the developments in applied linguistics over the past two decades regarding complex systems as well as an overview of current applied linguistics research being conducted from a complexity perspective. For those not yet familiar with complexity theory, brief backgrounds of key developments and concepts in complexity science are provided to begin.

Developmental Background

Due to the nature of this paper, the developmental background of complexity science provided here is necessarily brief. For a more comprehensive look at the background of complex systems, dynamics, and their related studies, refer to van Gelder and Port (1995), de Bot, Lowie, and Verspoor (2007), and Larsen-Freeman and Cameron (2008), the last to which this paper owes a great deal. Complexity science can be said to have had its foundation laid as far back as Isaac Newton (Mohanan, 1992), in whose day the inherently complex problem of calculating three orbiting celestial bodies such as the Earth, its moon, and the sun could not be solved. Still, it was not until the beginning of the 20th century that complexity science and math began to come into their own right with the French mathematician Henri Poincaré's work in non-linear dynamic systems (Larsen-Freeman & Cameron, 2008). Poincaré proposed a solution to the celestial three-body problem which helped lay the foundations for chaos theory, a branch of mathematics.

However, complexity science's true flourishing did not begin until after World War II. With the rise of computers, advances were made in mathematics (Larsen-Freeman & Cameron, 2008), leading to catastrophe theory and chaos theory, as well as work on cybernetics (Wiener, 1948) and artificial intelligence (Ashby, 1960). Around the same time, geneticists and biologists were developing theories to describe complex systems and processes, leading to general systems theory, dissipative systems exhibiting self-organization, and autopoietic systems which "change and build new structures while maintaining their identity" (Larsen-Freeman & Cameron, 2008, p.3), such as the human eye. Complex systems were also introduced to meteorology (Lorenz, 1963), from which the now famous "butterfly effect" concerning a system's dependence on initial conditions eventually derived. Synergetics appeared in the 1980s, followed by the application of complex systems theory in the areas of economics, epidemiology, and developmental psychology (Larsen-Freeman & Cameron, 2008). This last area is of particular interest to applied linguistics, as the two fields share much in common, with applied linguists adapting concepts and methodologies from developmental psychologists such as Thelen and Smith (1994). In applied linguistics, one of the first published works concerning complex systems was Mohanan's (1992) work on emergent complexity in phonological development. A short time later, Larsen-Freeman (1997) published her seminal paper formally introducing complex systems to the field of applied linguistics. While researchers in applied linguistics did not immediately latch on to Larsen-Freeman's proposed theory, the field has seen an ever-increasing amount of work from a complexity perspective.

Theoretical Background

As should be apparent from above, complexity science covers a wide range of fields and disciplines. Unfortunately, this can cause some confusion when trying to understand the basic principles of the theory while not inadvertently applying a concept from one field (the edge of chaos in math, for example) to another where it may or may not actually fit (fashion trends in business, say). This does not render a study of complexity impossible, but merely warrants proper caution when applying it in new areas. In order to facilitate such an understanding, a short discussion of important ideas in complexity theory is necessary.

To begin with, a system is complex if it has a variety of multiple interconnected parts "which connect and interact in different and changing ways" (Larsen-Freeman & Cameron, 2008, p.26), making the system dynamical as well. A classic example of a system that is not complex is a single pendulum swinging inside a grandfather clock. The pendulum swings back and forth on its pivot in a predictable pattern of motion that does not change. Were you to hang a second pendulum from the bottom of the first, however, the resulting construction would be a system exhibiting dynamical properties as the two pendulums interacted with one another. This dynamical system would also exhibit the property of non-linearity. The position of a non-linear dynamical system such as the double pendulum cannot be predicted any further than a few time steps into the future due to the complex nature of its components. In fact, the double pendulum is an example of a strange attractor, or state of chaos, in which the position of each pendulum never follows the same pattern twice, although all of its future positions are dependent on its initial or current position. It should be noted here that in complex systems theory, chaos does not equal anarchy or a lack of all order, but refers to a period of continuous unpredictable system change. However, this is not to say that the two-pendulum system is completely unknowable. The properties of the system force it to operate within a very definable set of boundaries, essentially the complete circumference of the lengths of the two pendulums added together. The system cannot operate outside of this boundary, but within its limits it is free to exhibit the full range of all possible configurations. Additionally, if it were a closed system, then eventually the attached pendulums will come to a halt at the point to which gravity pulls them. But if the system were open, or able to receive energy from outside, then the pendulums could continue to move indefinitely, albeit in a non-linear manner.

The idea of states mentioned above is another important aspect of complexity theory. All of the possible configurations of a system make up that system's state space, and configurations to which the system is naturally drawn are known as attractor states. For a more visual example which is also more complex, picture a small rocky island in the middle of the ocean. Maybe the island has some trees, some weeds and grasses, a thriving insect population, and houses a small colony of insect-eating birds. The state space of this island system, since it includes all possible attractor states, could potentially range from an insect buffet-like paradise for the birds, to, if something were to cause drastic change, a bald rock sticking out of the ocean whose only remaining tenants would be the bacteria left behind after the rest have disappeared. The island, though, as an open system existing in nature, exhibits another important feature of a complex, dynamical system: adaptability. When picturing an ecosystem such as our island, it is easy to imagine it as a static, stable entity that does not change as long as weather patterns, sunlight, etc. remain constant. This is not accurate, however, since any complex dynamical system is always changing. Change, write Larsen-Freeman and Cameron (2008), is “perhaps the most important feature” of a complex system (p.25). The island's ecology is one system, but it is made up of many interacting subsystems—the bird colony, insect colonies, trees, individual blades of grass, even the cellular structures of each organism—which are always acting on and being acted upon by other agents in the system. Thus, despite the island's appearance of stability, that very stability is only maintained through constant adaptation of all the island ecology's many parts. The island's attractor state is actually one known as the edge of chaos (Kauffman, 1995 in Larsen-Freeman & Cameron, 2008). A complex adaptive system (CAS) can actually exhibit the greatest degree of flexibility and stability when it is near chaos. If a system's attractor state is too strong, then adaptation becomes difficult; likewise, if an attractor state is unstable, then the slightest nudge may send a system into a state of chaos (Larsen-Freeman & Cameron, 2008).

Barring an outside influence, or perturbation, that is sufficiently strong, well-timed, or well-placed enough to disrupt the entire system, a CAS's component subsystems will most often adapt to the change by entering a new attractor state while the overall system ecology remains relatively stable. Our island may experience a typhoon, and even lose a tree or two, but its ecosystem will likely adapt to the new conditions and continue to function much like before. If a perturbation is sufficiently strong or well-timed, however, then the CAS of the island may be permanently altered to a new attractor state. For example, if a lightning strike ignited a fire that destroyed all the trees on the island, the ecosystem may be forced into a chaotic state as it self-organizes until a new system of subsystems and processes emerges. The system-altering perturbation does not have to be as dramatic as lightning, though. Because there are so many interacting parts and subsystems in any CAS, it is not always possible to predict what effect any perturbation may or may not have. For our island, it may be something as seemingly benign as one too few days of sunlight which weakens the plant life and causes a chain reaction of changes that continue until the system can self-organize and a new, possibly very different, order emerges. Such emergence is the final key concept in this conceptual background.

In order to move away from our useful but hypothetical island, let us use the CAS of a human being, in particular, the human mind. In their important work on cognitive development, Thelen and Smith (1994) describe the emergence of coordinated reaching and grasping in young children. As the children were developing, several separate systems, such as hand-eye coordination and the movement of joints, self-organized into a higher-level CAS through which the children were able to reach out and grasp an object. Until that moment when the various systems became self-organized, the children were unable to independently perform the action. Once the new system emerged, the children were capable of grasping objects. Human language works much the same way since it, too, is a CAS (The "Five Graces Group", 2009). As a person's language develops, whether a child through the stages of their first language (L1) or a learner of any age through their second (or additional) language, it is affected by the brain's level of cognitive development, the frequency and manner of language use, the physical environment, the learner's motivation(s), and even the society in which the learner exists (Larsen-Freeman & Cameron, 2008). All of these factors, many of which are CASs themselves, interact to form the CAS of language in an individual. As the CAS of the LL's language encounters perturbations, it is constantly adapting and self-organizing in response. During these system adaptations and self-organizations, previously non-existent characteristics can emerge, such as the common error in children acquiring English as their L1 and some adults acquiring it as their L2 who over-generalize the past tense *-ed* suffix to all verbs. Despite not hearing caregivers or native speakers use words such as "goed" or "eated", the CAS of the learner may produce such ungrammatical utterances while it exists in an attractor state where it has possibly noticed and internalized the *-ed* suffix but has not yet been exposed to a sufficient noticing and/or frequency of irregular verbs (or in some cases, the previously correctly produced irregular verb forms may have been superseded by the newly emergent *-ed* suffix) (Ellis & Larsen-Freeman, 2006).

Overview of Complex Systems in Applied Linguistics

The application of CAS theory to applied linguistics has really only been going on for the past 20 years or so. During that time, many ideas have come directly from developmental psychology, including work by Holland (1995), Thelen and Smith (1994), and van Geert (1991). Because of this close relationship, this overview will include not only applied linguistic work in CASs, but applicable research from developmental psychology as well.

Twenty years ago, Pinker and Bloom (1990) published a paper on the evolution of language and learners' language systems. They argued that complex human language, or grammar, has developed as an adaptation for communication, and could have done so according to natural selection. Pinker and Bloom were dealing with the literal evolution of language, but at the same time, van Geert (1991) was using the evolution of an ecological system as a metaphor for cognitive and language growth. He was writing about L1 acquisition at the time, but the comparison of cognitive (language) growth to an ecological or natural system is one that is still used today. The following year, Mohanan (1992) published his paper applying CAS theory to phonological development. Then came Thelen and Smith's (1994) book on dynamic systems theory (DST) in the cognitive development of children, a landmark work which is still extensively quoted and referenced in modern CAS and DST research.

The late 1990s saw some of the first evidence of CAS entering applied linguistics. Continuing previous work in cognitive linguistics, McLaughlin and Heredia (1996) wrote about second language acquisition (SLA) as a cognitive skill where processes are internalized by the LL's cognitive system. Their work helped to bestow the proper importance on the cognitive (processing) aspect of SLA, which was later incorporated into the sociocognitive approach argued for by Larsen-Freeman (2007) and favored by Larsen-Freeman and Cameron (2008). The following year, Larsen-Freeman (1997) published her seminal work on applying complexity theory—which she labeled chaos/complexity science—to applied linguistics. In her paper, Larsen-Freeman provides an extensive background of complexity and dynamical systems theory, addressing (but not limited to) non-linearity, contained unpredictability, chaos, initial conditions, the edge of chaos, restructuring, emergence, adaptivity, and organic language growth. Many of these topics have been discussed in the sections above, but reading Larsen-Freeman's important paper is recommended to anyone interested in complex systems in linguistics. The following year, van Gelder (1998) wrote a lengthy defense of applying DST in cognitive science in which he provided and refuted 12 objections to the dynamical hypothesis. Likewise, another influential paper furthering the case for applying complexity theory to linguistics was published by Ellis (1998) with a focus on emergence. In it, he called for a connectionist approach to language learning which is more comprehensive and uses complexity theory to combine the various fields and disciplines related to learning which are available to applied linguists.

For the next five years, applied linguistics was relatively quiet in regards to CASs and complexity theory. However, beginning in 2002, when Larsen-Freeman (2002) wrote a follow-up paper to her previous work (Larsen-Freeman, 1997) offering complex systems as a way to bridge the divide between the debate that was ongoing between a sociolinguistic and a cognitive linguistic approach to language learning, there was a dramatic increase in papers being published from a complex systems perspective. At the same time, DST work in cognitive development was continuing. Van Geert and van Dijk (2002) offered tools for studying intra-individual variability in human development, what they consider to be the key for any kind of cognitive growth. Also in their 2005 course book on SLA research, De Bot, Lowie, and Verspoor took a step toward integrating DST into the field.

In a preliminary small-scale attempt at investigating variation from a complex systems perspective in five English as a second language (ESL) learners over the course of several months, Larsen-Freeman (2006) applied some of the tools offered by van Geert and van Dijk (2002) in analyzing the five learners' production. Larsen-Freeman was able to demonstrate the importance of variation through studying both the averaged results for the group as compared to the individual learners' actual production. Interestingly, in accordance with van Geert and van Dijk, Larsen-Freeman discovered that each learner appeared to be progressing through her own path to acquisition, with production between learners varying widely, implying that, since no two people's cognitive systems are the same, the seemingly similar surface language learners arrive at may be achieved through rather different paths. Because of this, Larsen-Freeman stressed the importance of not averaging or smoothing out the variability in inter-individual data, but using it as an indicator of individual growth. Part of the difference in LLs' linguistic development, according to Ellis and Larsen-Freeman (2006), is through the frequency of language use and exposure, which has a direct impact on what emerges from any learner's cognitive system.

The following year, as the debate between sociolinguistics and cognitive linguistics continued, Larsen-Freeman (2007) provided a further push toward a combined sociocognitive approach through complexity theory. At the same time, de Bot, Lowie, and Verspoor (2007) furthered the previous offering of research tools from van Geert and van Dijk (2002) by applying DST to SLA using tools developed in other social science disciplines. De Bot, Lowie, and Verspoor also supported combining the social and the cognitive to produce an overall theory of language development through a DST perspective. Some of the same researchers also published a subsequent study (Verspoor, Lowie, & van Dijk, 2008) using DST to investigate intra-individual variability in language learning. They also called for a DST research methodology in language development including longitudinal data gathering, dense observations analyzed in-depth, and different kinds of variability on different levels, all of which should be centered around times of increased variability, which may indicate cognitive development. Additionally, they found that high intra-individual variability is positively related to language learning through the development of learner strategies. By this time, complex systems theory had advanced in the field to the point where Plaza-Pust (2008) even called for a rejection of the universal grammar (UG) paradigm. She based her rejection on language's emergence through the self-organization of a learner's system due to substantial evidence being accumulated through use. When enough system-internal conflict has arisen from a lack of equilibrium brought on by increasing complexity, then the system adapts, or moves into a new attractor state.

Finally, in the past two years, more work is being done on applying complexity theory to different aspects of language development and change. Ellis (2008) has proposed a complexity-based process by which language undergoes change based on frequency of use as well as type and token frequency. He gives the changes that have occurred to produce the reduced form of *gonna* in English—despite its separation from the *be* verb—as an example of this process of change. Van Geert (2008) has described language growth logistically as evolutionary steps which operate under evolution rules in time and limited resources. Furthermore, it was in this same year that Larsen-Freeman and Cameron (2008) published their book on complex systems in applied linguistics. Serving as both an introduction to complexity theory and a demonstration of DST research in action, the book also provides a series of questions to encourage thought modeling of complexity in applied linguistics, a "complexity toolkit" (Wilson, 2002 in Larsen-Freeman & Cameron, p.229) for conducting research, and a list of eight "[m]ethodological principles for researching language and language development" (p.241). To date, Larsen-Freeman and Cameron's book is the definitive work on complex systems in applied linguistics. However, in a special issue of the journal *Language Learning,* the first collection of complex systems research in applied linguistics was published and begins with a position paper by The "Five Graces Group" (2009) on language as a CAS, their preferred term. Now that complexity theory has been introduced in the field of applied linguistics and has started to attract interest, we can only assume that research and work in CAS theory has just begun and that the real test of this approach's appropriateness in applied linguistics is now underway.

Current and Future Complexity Research in Applied Linguistics

As mentioned in the previous section, the special issue of *Language Learning* published in 2009 is one of the first collections of complexity-based work in applied linguistics. Now that a theoretical framework has been offered and is being developed, researchers are beginning to explore how language viewed as a CAS can aid in the understanding of human language learning. Much of the work provided in that special issue can be divided into two main categories: language acquisition and development based on its usage (Beckner & Bybee; Ellis & Larsen-Freeman; Christiansen & MacDonald; Matthiessen; Mislevy & Yin) and language's change and evolution as learners interact with the CASs of other people as well as the environment (Blythe & Croft; Boyd, Gottschalk, & Goldberg; Schoenemann; Cornish, Tamariz, & Kirby; Dörnyei, 2009a). The work covers many different areas and disciplines, which is only appropriate for a theory based on complexity. Beckner and Bybee, through their corpus analysis of the structure of complex prepositions, concluded that those syntactic structures emerge from local use and, like language itself, can change over time. Their conclusion seems to be in line with Ellis's idea of language change through usage (2008) and how by using language we are also changing it, a concept which Larsen-Freeman and Cameron (2008) likened to the fact that walking through a field affects both the walker and the field. In a similar vein, Ellis and Larsen-Freeman report on the similarities in the usage-based acquisition of prototypical verb-argument constructions (VACs) between human ESL learners and a computer simulation. They found that, through the use of simple recurrent networks (SRNs), the simulation was able to exhibit a preference for prototypical VACs similar to data taken from corpora of native and non-native English speakers, implying that frequency of use and input play a large part in learners' SLA. In the realm of grammatical recursion in use, Christiansen and MacDonald found that recursion is an acquired skill, which they demonstrated through the use of simulated models of recursion. The models were also able to accurately predict grammatical recursion, implying that the skill of recursion is, indeed, acquired through and developed by use. One CAS term which has not yet been touched on in this paper is iteration. Much of the above usage-based research, as well as language evolution and change, is related to iteration and iterative learning. The idea of learning through slightly different iterations of the same situation or activity, or learning something new based on what came before, is one inherent to complexity theory in applied linguistics (de Bot, Lowie, & Verspoor, 2007) as well as cognitive development in general (van Geert, 2003).

Research into language as a CAS is, of course, ongoing and promises to continue thus. As language as a CAS research expands into different linguistic areas, we can expect to see more work being done from a CAS approach. For example, from a theoretical approach, Finch (2010) has investigated the effects of critical incidents and initial conditions—or the butterfly effect—on students' subsequent language learning later in life. Similarly, in her dissertation, van Koert (2010) has used the idea of fractals, or self-similarity, in complex systems to analyze ESL learners' writing. She found that learners' systems, even at different ability levels, exhibited fractal change according to Zipf's power law of frequency (Zipf, 1935 in van Koert). The higher a learner's level, the more variety of constructions, verbs, etc. were employed in writing, which seems to support the notion that language learning, as a CAS, develops fractally (Larsen-Freeman & Cameron, 2008).

From a more qualitative approach, research has recently been carried out on motivation in language learning as well, based largely on the extensive work of Dörnyei (2000; 2005; 2009b; etc.) in that field. Nitta and Asano (2010) have investigated, as part of an ongoing longitudinal study, the variation of student motivation in an EFL setting at the university level. From their complexity-based research, Nitta and Asano found that many interacting factors, not just one, contributed to change in student motivation. This is not surprising, in and of itself, but supports treating language learning as a CAS. Csizér, Kormos, and Sarkadi (2010) have also studied EFL learners' motivation, but in combination with dyslexia. They treated learners' cognitive systems as coadaptive, and produced a model of LL motivation which captures the dynamic change exhibited by learners.

Finally, Seedhouse (2010) has investigated interaction in the L2 classroom as a CAS. He found that L2 classroom interaction does not seem to follow a linear progression, but often appears to behave dynamically. He also concluded that the interaction was iterative, with one action preparing the system for the next, the latter being dependent on the former.

As should be evident by this point, DST and CASs are being applied to linguistic research in a wide variety of areas. As this preliminary work is shared, it is encouraging to note that the results seem to be supportive of applying the CAS theory to language learning and development in applied linguistics. It is most likely safe to assume that we will see an increase of research into language based on DST, CAS, emergentist, connectionist, and usage-based approaches. As much of the work carried out thus far seems to be centering on a few specific areas—language evolution, emergence in syntax through usage, and learner motivation—it seems necessary that CAS research be expanded into other aspects of language and its acquisition. In an attempt to aid in such an effort, several issues which have yet to be addressed from a CAS perspective will be introduced below.

First, one of the most challenging issues in an application of complexity theory to language and language learning research is that of collective variables. When dealing with a complex system of any kind, even one with fewer components than a human learner, traditional reductionist cause-effect methodologies are ineffective (Larsen-Freeman, 1997). There exist too many parameters in a CAS to only investigate a single one and hope to determine its precise role in the entire system. Instead, what must happen is the determination of collective variables within the system (Larsen-Freeman & Cameron, 2008). By grouping system parameters together, we may treat them as one variable, allowing study of that variable's impact on the system. However, this seems as if it could potentially cause future discord in regard to the effectiveness of a CAS method; any future research should carefully define and defend its choice of collective variable(s).

Concerning SLA, there are a few areas that have yet to be thoroughly considered that may yet provide insight into language learning. The interlanguage (IL) development of LLs as they progress toward a system more closely resembling the surface production of a native speaker is, according to CAS theory, necessarily unique to each individual. However, a CAS approach to the effect of a LL's L1 on their IL system may help to clarify unanswered questions in IL research. Additionally, comparing the ILs of learners in L2 and FL (foreign language) settings may provide illumination into the different effects and amounts to which the learning environment contributes to language development. There are many FL learners around the world who would benefit from a better understanding of how best to create a productive FL learning environment. Furthermore, if language is a skill (McLaughlin & Heredia, 1996) or, more likely, a set of skills and strategies (Verspoor, Lowie, & van Dijk, 2008) which interact in complex and dynamic ways, then looking at the interaction of different skills in language use may aid in the understanding of what cognitive constructs are required in order for successful communication and/or language growth to occur. If such a skill set were definable, then it may be possible to track its components' development or even teach their use to leaners.

Investigating LLs' contribution to their own learning may present interesting qualitative results as well. For instance, form-focused study or instruction may play a positive role in L2 learners' acquisition beyond childhood. But learning to what extent such a focus on form has a lasting effect on a learner's language system would seem a vital question for LLs in any context. If language use were determined to be paramount in long-term system-changing growth, then focusing on form in FL classrooms too much may be detrimental to LLs. Moreover, since language learning is one type of cognitive growth which requires both internal and external resources (van Geert, 1991) as well as restructuring and successful use of strategies, further research into how these processes take place in SLA seems necessary. If any of these three areas can be improved through instruction or use, it may be possible to increase the cognitive tools at learners' disposal. This, in turn, may be related to positive effects on learners' language growth.

Conclusion

This paper has attempted to provide an overview of the theory of complexity, its background, and how it is being utilized in applied linguistics. The sections have been necessarily brief due to this paper's limited scope, but each was an attempt to provide key concepts and developments in applied linguistics. These concepts and developments may possibly be helping to alter the cause-and-effect research paradigm of reductionism in linguistic research to one which embraces complexity and the interconnectedness of all a learner's many systems which help to make up language as a CAS that exhibits emergent properties and evolves over time. As the field of linguistics progresses, it is becoming more and more apparent that all of its various fields and sub-disciplines are necessary to create a complete, dynamical picture of language. Such a holistic approach may seem daunting at the onset, but the application of complexity theory to language and language learning may be both the means and the end to a more complete understanding of human language.

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