

A complex dynamic systems approach to L2 development as a metatheory of language learning and teaching

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Abstract The CDST approach to SLA/T is a metatheory focusing on the emergent and usage-based process of second language development, which is strongly individually owned. Even though aspects of the CDST research perspective are commensurable with all usage-based, ecological, and syncretic views of language learning, the approach has a distinct theoretical foundation in complexity theory and requires distinct methodologies that acknowledge the iterative nature of development.

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1 Positionality

My trajectory in applied linguistics developed from theoretical linguistics to a fascination with phonetics and phonology, to psycholinguistics. I became convinced that we can only understand L2 learning by conducting carefully controlled experiments analyzed with sophisticated statistics based on large and normally distributed samples to ensure generalization – until that day in 2004, when Kees de Bot, Marjolijn Verspoor, and I got involved in Marijn van Dijk's (2004) doctoral dissertation, a dynamic systems theory study about first language acquisition in developmental psychology. This case study meticulously followed the process of language development over time with a dense series of observations, sparking our interest in dynamic systems. We immersed ourselves in the literature and explored how this framework could be applied to SLA/T. Among many other articles, we also hit on the article that Diane Larsen-Freeman wrote in 1997, in which she already argued for the application of complexity theory to SLA.

Now, 20 years later, with numerous PhD studies, conferences, discussions, and articles behind me, I am still learning. I am now convinced that a holistic, longitudinal, ecological, and usage-based approach that acknowledges the complexity of the process should guide our investigations into the principles and mechanisms of L2 development

to inform language pedagogy. While we will also need large and controlled “traditional” group studies employing multilevel analyses and linear mixed-effects models to identify global grand-sweep effects, we must recognize that we can only answer the questions our method allows us to answer. Studies inspired by CDST are simply better equipped to answer questions about the process of development.

2 A dynamic perspective

A distinctive characteristic of the CDST approach to L2 development is its process-oriented perspective, also known as “process ontology” (van Geert & de Ruiter, 2022). CDST is a meta-theory of change across time, offering a suitable model to describe and explain L2 development. The foundation of the CDST research perspective lies outside the field of L2 learning and teaching and is found in democracy and in physics to explain naturally occurring phenomena. Everywhere around us, we can see embedded and self-similar structures that result from self-organization in complex systems, from broccoli to rock formations, from ripples in the sand to branching rivers, and including the statistical and syntactic structure of language (Rosmawati & Lowie, 2024).

2.1 Dynamic systems

Systems are entities composed of coupled components working together to achieve a collective purpose, and understanding systems involves studying their components, interconnections, behaviors, and interactions with external influences. This interdisciplinary approach has been crucial in solving complex problems across many fields. Complex dynamic systems consist of an infinite number of changing components. The continuous interaction of these components will lead to emerging patterns, as illustrated by ripples in the sand formed by wind, temperature, and humidity, referred to as self-organization. Perturbations, such as a person walking through the sand, can temporarily disrupt these patterns, but they re-emerge if the subsystems remain unchanged. However, when one or more of the subsystems change, this can lead different patterns to emerge. A typical characteristic of self-organizing dynamic systems is the self-similarity of embedded subsystems. Each time we zoom in, we can discern self-similar patterns, referred to as fractals.

Another concrete example in the physical world is the weather. The weather at any point in time results from the nonlinear interaction of numerous subsystems like temperature, humidity, and wind. Using dynamic models, we may be able to predict tomorrow’s weather and perhaps the weather for next week, but long-term predictions are increasingly uncertain. Only very global predictions can be made based on statistical data – in the Northern Hemisphere, the temperature in April is bound to be higher than the temperature in February. This dynamic approach has been widely accepted in accounting

for a wide variety of phenomena, from subatomic motions, fluid flow, solar systems, and ecosystems to social systems like economies or organizations.

2.2 Complex dynamic systems in cognition

CDST's explanatory power extends to human cognition and language development. Influential works like Thelen and Smith's (1994) *A Dynamic Systems Approach to the Development of Cognition and Action* and Port and van Gelder's (1995) *Mind as Motion* shifted the view of cognition from static structures to dynamic networks of nonlinear elements. These studies emphasize timing, periodicity, and the dynamic interplay between perception and motor control, highlighting the continuous coevolution of the cognitive system with environmental stimuli:

The cognitive system is not a discrete sequential manipulator of static representational structures; rather, it is a structure of mutually and simultaneously influencing change. Its processes do not take place in the arbitrary, discrete time of computer steps; rather, they unfold in the real time of ongoing change in the environment, the body, and the nervous system. The cognitive system does not interact with other aspects of the world by passing messages or commands; rather, it continuously coevolves with them. (van Gelder & Port, 1995, p. 3)

The coupled subsystems may be embedded, which implies that subsystems in cognition may also be embodied.

2.3 Change over time

The dynamic process is characterized by iterative development, where each iteration involves the interaction of all relevant subsystems to update the system's state. This process leads to a sequence of states or behaviors over time, with each step emerging from the interaction of changing subsystems, a part of self-organization. Since each step involves numerous subsystems, each developmental step is unique. As Thelen (2005) noted, "Every act in every moment is the emergent product of context and history, and no component has causal priority" (p. 271). This implies that for the explanation of the development of coupled systems, multicausality must be the norm.

2.4 Language development in a framework of complex systems

If language can be regarded as a natural system, the assumption is that language development follows the laws of complex dynamic systems: self-organization through the interaction of subsystems, leading to complexity, variability, and continuous interactions. Key characteristics include:

1. **Nonlinear relationships:** Language development is influenced by social and psychological factors and language contact opportunities. Changes in one part can disproportionately affect others, leading to emergent properties and behaviors. All subsystems are open and are potentially coupled. Language learning and language use may change as a function of its context, but the context will change as a function of the language used.
2. **High variability:** Language use varies across speakers, contexts, and situations, reflecting the adaptability of language. Variability in language production is related to developmental steps (Lowie & Verspoor, 2015; Verspoor et al., 2008, 2021).
3. **Emergent properties:** Language features like grammatical patterns arise from component interactions and cannot be predicted solely from individual elements (Harrison & Raimy, 2007). Language learning is an emergent process (Ellis, 1998).
4. **Complexity:** Language has hierarchical organization, self-similarity across levels, and sensitivity to initial conditions, contributing to its richness and adaptability (Larsen-Freeman & Cameron, 2008). Self-similar fractal patterns in L2 development have been found both in linguistic structure (Evans & Larsen-Freeman, 2020) and in the time domain (Lowie et al., 2014).
5. **Language change:** Language evolves due to social, cultural, and historical factors, involving complex interactions between speakers, communities, and external influences (Elman, 1995).

By viewing language through a CDST lens, we can gain insights into the underlying mechanisms driving language structure, change, and variation.

3 Empirical: Methodological consequences for CDST-inspired research

CDST encompasses both dynamics and complexity, leading to two main research lines: The first explores the intricate relationships among system components, while the predominant focus is on the process of change, requiring a longitudinal perspective. Development occurs at various timescales, with variability being a key characteristic. Therefore, the density and quantity of observations should align with the expected granularity of development (Lowie, 2017). For instance, studies have ranged from over 500 observations in a 30-minute-naming task (Plat et al., 2018) to around 40 observations in 6 months (Verspoor et al., 2021) and 60 observations over nearly 50 years (Trinh et al., 2024).

CDST research primarily involves individual case studies because similar groups of individuals are rare. Each step in an individual's language development is unique, resulting from an infinite number of coupled subsystems (Lowie & Verspoor, 2019; Molenaar, 2015). Critics argue that the focus on case studies limits the ability to generalize findings to larger populations (Pallotti, 2022). However, generalizing group study results to indi-

vidual participants is equally problematic. Group studies often fail to reflect individual patterns, highlighting the need for complementary research methods. Group studies address variable interactions at single points, while CDST studies offer insights into the developmental process over time. For example, outcome-focused studies might compare the impact of the age when L2 learning starts on L2 pronunciation quality (Derwing & Munro, 2013). In contrast, process-focused studies might examine how vowel production in an L2 learner evolves, initially fluctuating between L1 and L2 realizations before stabilizing toward target pronunciations (Verspoor et al., 2021). In other words, while group studies are most suitable to explore the effects of several variables at one point in time, longitudinal case studies are most suitable to explore the principles and mechanisms of the developmental process.

Several techniques facilitate observing groups of learners over time. Data-driven methods, such as cluster analyses, group learners based on their observed behavior (like learning strategies) rather than pre-established criteria, allowing broader conclusions beyond single-case observations (e.g., Peng et al., 2022). Some studies use dynamic models to capture general principles of change (Caspi & Lowie, 2013), while others employ retrodictive modeling to retrospectively make inferences about conditions (Elahi Shirvan & Talebzadeh, 2020). These techniques help analyze complex dynamic data (Hiver & Al-Hoorie, 2019).

Recognizing that research methods only address specific questions is crucial. Distinguishing between product-focused and process-focused analyses, each with distinct research questions, allows us to move beyond generalization as the sole objective. Multiple case studies can reveal the principles and mechanisms of language development.

4 Implications for teaching

When learning is characterized as a highly individual process, we would predict that teacher-centered learning in large groups is less successful in catering to learners' individual needs compared to student-centered learning that employs active learning principles. The self-organizing principle of complex dynamic systems has two implications. First, rather than “teaching” languages, the teacher's task is to create optimal conditions for learning to develop. These conditions should allow individual learners to build on their own learning experiences and encourage them to use language freely in a safe environment. Consequently, the L2 learner should be regarded as a competent learner, not as an incomplete and at best partially successful imitation of a native speaker of the target language (see, e.g., Cook, 1992). A second implication of self-organizing systems is that phase changes may occur after a perturbation. A perturbation can be a change in the environment or an experience that leads to an eye-opener. Perturbations can take place at a variety of levels, magnitudes, and time scales. For instance, participating in meaningful interaction in a scaffolding context may create a strong perturbation for

many learners, while learning grammar rules by heart may create a perturbation for only a few. Even though learning is a highly individual process, it rarely happens in isolation.

Our studies have shown considerable intralearner variability over time, which can be seen as a manifestation of the learning process. No variability implies that no learning is occurring (Lowie & Verspoor, 2015). This suggests that a personal portfolio, demonstrating the learner's evolving communicative competencies, would be a fairer representation of the learner's proficiency than a language test at one moment in time.

Glenn Levine (2020) worked out a “human ecological pedagogy” for language learning, based on a combination of sociocultural (e.g., van Lier, 2004) and CDST principles. In his monograph, he showed how CDST helps us identify a responsive, flexible set of guidelines for teaching, rather than any one method or set of methods – that respond to the realities of language teaching and learning in our highly complex, globalized world. The “resourceful teacher,” he argued, “would be one who is aware of the complexity in the classroom at any given moment and can utilize it to make informed decisions about what she or he may engage students in toward intended outcomes” (Levine, 2020, p. 16).

5 Conclusion

CDST is a metatheory that provides a systems approach to L2 development. It focuses on the developmental process and aims to analyze and explain the principles and mechanisms of change. CDST is holistic, acknowledging the potential coupling of all subsystems involved in development. Variability is seen as a manifestation of self-organization and is valued as a crucial source of information. The most significant implication for research methodology is the use of multiple longitudinal case studies with numerous observations over time. For teaching, the most important implication is that the individual nature of language development should be considered in language pedagogy.

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