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# DYNAMIC SYSTEM THEORY (DST) IN SECOND LANGUAGE ACQUISITION (SLA) STUDY: METHODOLOGY AND RESEARCH FOCUS

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**Abstract:**
Dynamic Systems Theory (DST) is a significant framework in Second Language Acquisition (SLA) studies. Nevertheless, this domain faces fragmented experimental methods and theoretical debates. By providing a critique and highlighting the challenges in recent studies, this review serves as a critical reference for researchers and educators, aiming to foster a more unified and theoretically robust understanding of DST and provide future direction for language educational research. This study summarizes DST applications in SLA by examining 33 empirical studies published between 2020 and 2025, selected through a rigorous four-phase procedure that aligned with PRISMA 2020 guidelines. These studies are analyzed according to their focus areas, methodology (research method and data analysis model), and engagement with DST. The results highlight the prevalence of longitudinal, multi-layered, and methodologically diverse designs in these studies that aim to capture the nonlinearity, individual variability, and dynamic interactions within the framework of DST. Although the theoretical propositions of DST have been validated, limitations persist in the restricted generalizability of the results and the insufficient clarification of underlying mechanisms. The conclusion stresses the need for future studies with extended observation, dense longitudinal data, and integrated methods to produce generalizable results. This study supports researchers and educators in understanding advancements, constraints, and future directions of DST applications in SLA.

**Keywords:** Dynamic Systems Theory (DST); Complex Dynamic Systems Theory (CDST); Complexity theory; Second Language Acquisition (SLA); second language learning

## 1. Introduction

The Dynamic Systems Theory (DST), also referred to as Complex Dynamic Systems Theory (CDST), has emerged as a significant framework in second language acquisition

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(SLA) research. Unlike traditional linear models, DST posits that language develops as a result of a learner using it in situations that involve interaction with other language users, emphasizing a participant-relevant sensitivity in contextual dimensions of language use (Firth & Wagner, 1997; Gu, 2023). In other words, DST takes an ecological perspective to examine the process of second language learning. Various empirical studies confirm the possibility and effectiveness of DST-inspired approaches towards the study of L2 development (Murakami, 2016; Yu & Lowie, 2020). Based on the underpinning perspective, the process of second language acquisition is viewed as an evolving and complex system interconnected with a range of internal and external factors. Variability and nonlinearity are the main characteristics of this system (Chang & Zhang, 2021). Variability refers to the phenomenon that language use varies across speakers, contexts, and situations (Atkinson *et al.*, 2025). There are developmental trajectories and complexities evident in SLA that cannot be generalized to individual learners, vice versa (Tabari & Wind, 2025). For instance, L2 adult learners typically keep more competing forms than L1 acquisition (Evans & Larsen-Freeman, 2020). Nonlinearity refers to the phenomenon that language development is not continuous and is affected by social and cognitive factors. The attractor or preferred states are assumed to be a result of self-organising, which is influenced by cognitive capacity and linguistic environment (Li *et al.*, 2023; Sowers-Wills, 2021). Furthermore, empirical evidence consistently validates the tenets of DST, demonstrating that language learning involves cross-disciplinary approaches since they are linked, self-organizing, and co-adaptive (Chang & Zhang, 2021). For instance, the relationships among different subsystems were mostly negative, whereas the correlations within the same subsystems were positive. (Rokoszewska, 2022). Recent scholars have also extended the areas of studies in SLA to explore more variables in DST beyond the traditional research subjects, for instance, motivation and foreign language enjoyment. These studies argue that L2 development is unstable and influenced by internal cognitive factors and external factors (Kliesch & Pfenninger, 2021; Li *et al.*, 2023). In summary, recent studies investigate the evidence from multifaceted developmental trajectories that reveal the characteristics of DST in SLA (Abdi Tabari & Wind, 2025).

Despite the expanding application of DST in SLA, the field currently faces substantial fragmentation. During the development of the theory over time, followed by the introduction of new approaches, various variabilities in grand theoretical presumption and empirical databases emerge, leading to imbalance (De Bot *et al.*, 2007). Divergent methodological approaches and theoretical interpretations are criticized for their misalignments between theoretical assumptions and empirical validation (Abdi Tabari & Wind, 2025). Although the increasing exploration of DST in SLA from various perspectives is emerging, the lack of synthesis and common sense in terms of research methods, especially the updated technology for depicting the process of SLA, leads to debates about methodological rigor and effectiveness. Furthermore, the absence of a recent systematic review exacerbates the disarray, leaving critical discussions regarding

methodological and theoretical advancements inadequately addressed. Consequently, researchers and educators who seek a recent understanding of DST's current state of applications in SLA lack systematic guidance for future directions.

By synthesizing recent studies of Dynamic System Theory (DST) in SLA, the significance of this study lies in identifying key areas leveraging the DST perspective to improve L2 research and instruction support. Future researchers can prioritize the unexplored themes to discover the underlying mechanism in SLA. Additionally, selecting a rigorous research design with combined methods can facilitate the testing of hypotheses of DST. Future educators and practitioners should consider language as a complex system where multiple factors interact, pay attention to variability in individual learns and unique learning trajectories, and adopt comprehensive evaluative testing and teaching strategies. To summarize, this review serves as a critical reference for researchers and educators, aiming to foster a more unified and theoretically robust understanding of DST and provide implications.

This systematic review conducts an in-depth, synthesizing analysis of relevant empirical studies. By summarizing the research focus, methodology, and development of DST, this study aims to provide a comprehensive overview of recent studies. The contribution of this study lies in its potential to clarify the areas where DST is applied, the methodologies, and how the theory is challenged, refined, and developed, thus fostering a more robust hypothesis and methodologies. By critically analyzing recent trends and identifying persistent issues, this study will underscore the need for methodological integration and refinement of study focus in future studies.

To examine previous studies, the review will dive into the following questions:

**Q1**: What are the characteristics of the research methodologies in these studies, including research methods (quantitative, qualitative, mixed-methods) and research designs?

**Q2**: What are the prevalent research domains in these studies? How do these studies contribute to the theoretical propositions of DST, specifically by challenging, developing, or confirming its core characteristics?

## 2. Method

This systematic review strictly follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and comprehensiveness in selecting and synthesizing relevant literature. The process comprises four phases: identification, screening, eligibility assessment, and inclusion, as detailed in Figure 1.

### 2.1 Search Strategy

The search was conducted in the SSCI journals of the Web of Science Core Collection. The strategy was designed to capture all empirical studies on DST applications in SLA

published between 2020 and 2025. Keywords were applied as "topic" searches: (a) second language acquisition or SLA or L2 acquisition or foreign language learning, and (b) "dynamic systems theory" or "DST" OR "complex systems" OR "nonlinear dynamics. To prioritize recent studies, publication years were restricted to 2020-2025. The initial search showed 112 records.

### 2.2 Filtering Process and Inclusion Criteria

Following the initial identification, a rigorous filtering process was implemented to select studies meeting the inclusion criteria and exclude those that did not, as detailed in Figure 2.

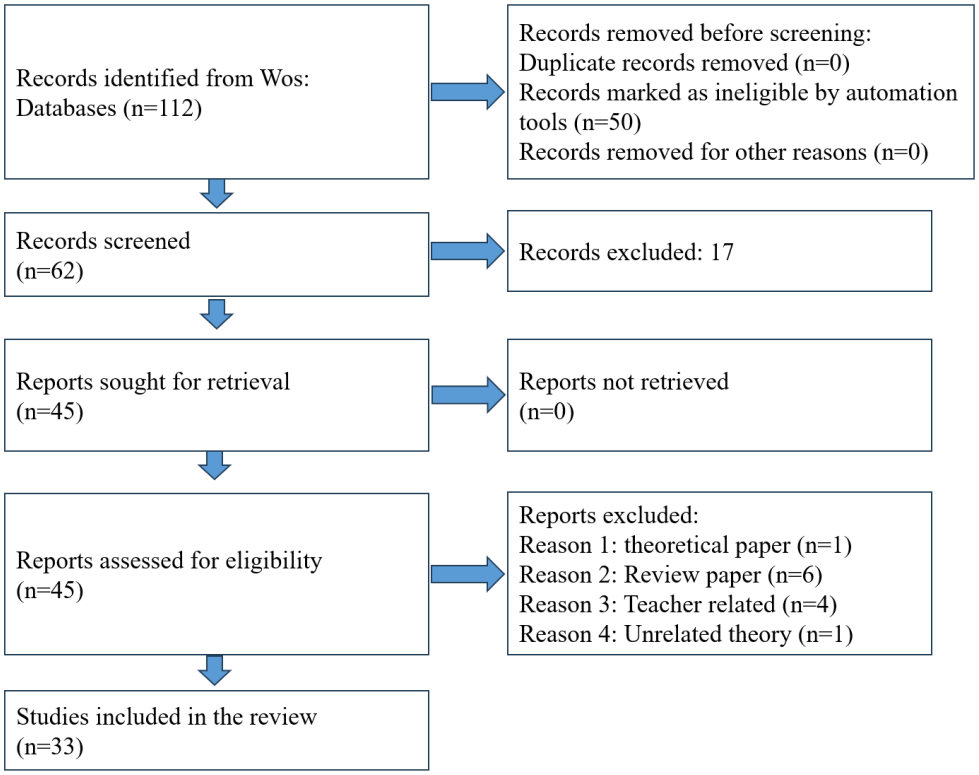


**Figure 1:** Process of literature selection

| Intervention | Criteria |
|---|---|
| Population | Include: Student<br>Exclude: Teacher, educator, instructor |
| Topic Relevance | Include: DST, second langauge acquisition<br>Exclude: Irrelevant with DST and second language acquisition |
| Study Design | Include: Empirical studies (e.g., experimental, quasi-experimental, observational, qualitative, mixed methods)<br>Exclude: Review articles, commentaries, opinion pieces, news/blogs |
| Publication Year | Include: 2020-2025<br>Exclude: Before 2020 |
| Publication Type | Include: Peer-reviewed journal articles<br>Exclude: conference papers, academic theses, Unreviewed articles, editorial material |
| Language | Include: Published in English<br>Exclude: Non-English publications |

**Figure 2:** Inclusion and exclusion criteria

In terms of inclusion criteria, only empirical research articles that present data and findings were included, which guarantees the evidence-based analysis of DST applications in SLA. Reviewed articles must be published in a peer-reviewed journal indexed in the Web of Science Core Collection, specifically SSCI journals, which ensures high academic quality. Studies required to utilize or examine Dynamic Systems Theory (or related terms like "Complex Dynamic Systems Theory", "Complex Theory", or "Nonlinear Dynamics" in the context of Second Language Acquisition (SLA) and are published in English were included.

In terms of exclusion Criteria, theoretical papers, conceptual articles, and review articles were excluded (Zhang & Zou, 2022), which aligns with the focus on empirical evidence. According to PRISMA flow, 1 theoretical paper and 6 review papers were excluded. Secondly, studies that primarily focus on teachers, educators, or instructors who are involved in SLA were excluded. According to PRISMA flow, 4 teacher-focused papers were excluded. Studies that mentioned DST or SLA but were not centered on its direct application or investigation of DST in SLA were also excluded. 1 study that focuses on irrelevant theory with DST is excluded. Lastly, to maintain a high quality of reviewed papers, conference papers, academic theses, unreviewed articles, and editorial articles were excluded.

The filtering process unfolded in two main stages. In the screening (Title and Abstract) stage, all identified records were screened by the author to remove irrelevant articles and duplicates. Automation tools identified and excluded 50 ineligible records. 17 records were excluded in this stage. In the eligibility assessment (Full-Text Review) stage, the full texts of the remaining articles were evaluated against the detailed inclusion and exclusion criteria. 12 papers were excluded based on the reasons aforementioned in

the exclusion criteria. Ultimately, a total of 33 empirical studies were selected for data extraction and analysis (See Appendix A1 for the list).

### 2.3 Coding Scheme

Given the focus on DST applications in SLA, the coding scheme was grounded in the core tenets of DST, supplemented by established frameworks for analyzing study focus, key characteristics, and research method.

The coding scheme included the following three dimensions. The categorization of research focus was coded manually according to the aspects of themes investigated, including linguistics, cognitive, and others, adapted from the classification of Shadiev and Yu (2022). Specifically, the studies were classified in categories of "writing", "speaking", "foreign language enjoyment (FLE)", "others", "individual differences", "motivation", "listening", and "syntax". According to their contents, some articles can be categorized under two research focuses; however, the final classification is determined by their primary content. The categorization of key characteristics in writing studies is adapted from the classification of Atkinson *et al.* (2025), including nonlinear relationships, high variability, emergent properties, complexity, and others. Notably, the classification is based on the main findings, deliberately overlooking other secondary characteristics. The Classification of research methods consists of quantitative, qualitative, or mixed-methods (Zou *et al.*, 2022). Detailed coding types, subtypes, and sources are shown in Appendix A2.

## 3. Results

### 3.1 Methodology of Studies

To answer Question 1, this part identified the research methods and explored their respective implementations.

#### 3.1.1 Research Method

The methods in these 33 studies involve quantitative in 17 articles (52%), qualitative in 5 articles (15%), and mixed-methods in 11 articles (33%) (Figure 3). More details are shown in Appendix C.

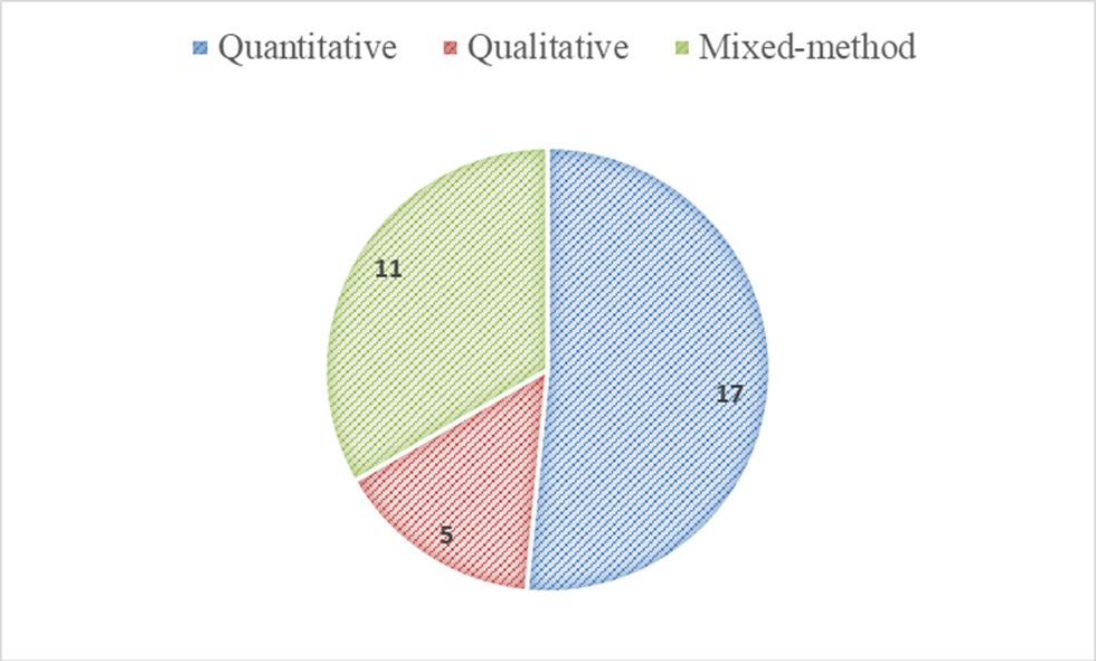


**Figure 3:** Number of research methods

### 3.1.2 Quantitative Study (n=17)

These studies employ a wide range of research designs, with the emphasis on longitudinal and cross-timescale approaches, to capture the dynamic, nonlinear, and developmental process of SLA. Specifically, longitudinal research designs ensure the generalizability of results, mitigating the shortcomings of insufficient participants in the experiment (Abdi Tabari & Wind, 2025). Dense temporal data collection across seconds, minutes, weeks, and months reveals nonlinearity and interconnectedness in the emergence of patterns (Evans & Larsen-Freeman, 2020; Jung *et al.*, 2020; Rokoszewska, 2022). Integrative design combined with individual-level and group-level analyses facilitates a more holistic understanding of DST (Duan & Shi, 2024; Li & Zheng, 2025).

Advanced statistical models were designed to depict the inherent multivariate and complex nature of SLA. For instance, latent change score (LCS) models analyze dynamic trajectories of the variables within-person and between-person (Kruk *et al.*, 2023). Generalized additive mixed models (GAMMs) are capable of modeling both linear and nonlinear dynamic developmental trajectories (Kim *et al.*, 2024; Kliesch & Pfenninger, 2021). Other models include structural equation modelling to illustrate the organization of componential abilities that interact between multiple factors (Yu & Dong, 2020), individual growth curve models (IGCM) to reveal a development pattern characterized as a gradual-to-rapid trend of acceleration over time (Li & Zheng, 2025), and Group Mixture Model (GMM) to detect and visualize the heterogeneity of language development (Yu & Peng, 2025).

Furthermore, multiple analyses are also used to help interpret the process of SLA in which DST characteristics are involved. For instance, dynamic analyses using moving min–max graphs and moving correlations (Yu & Lowie, 2020), as well as fractal analysis,

appear to be fruitful analytical tools to discern the dynamic relationships among multiple parts as they interact over time (Evans, 2020). A time-series cluster analysis identified the variability of developmental patterns between learners in phase shift and the interaction of the sub-system. (Li & Zheng, 2025).

In summary, the adoption of advanced research designs, statistical models, and analyses varied in different studies, which is crucial and effective for detecting a more accurate representation of the developmental process in SLA.

### 3.1.3 Qualitative Study (n=5)

These studies highlight a significant trend in in-depth, longitudinal, and individual-centered focus. Recent studies that adopted a case study approach tracked the developmental trajectories by delving deep into the variability of individuals (Zhang & Zhang, 2025; Zhou, 2023), using semi-structured interviews (Li *et al.*, 2022) and longitudinal narrative inquiry supplemented by materials and interviews (Yung, 2025). Nevertheless, although the idiodynamic method was applied on a micro-timescale to demonstrate changes over time (Li *et al.*, 2024), it is potentially criticized for recruiting a limited number of participants in the experiment. (Abdi Tabari & Wind, 2025).

### 3.1.4 Mixed-method Study (n=11)

Recent studies also adopt mixed-method studies, integrating both quantitative and qualitative approaches to investigate SLA. It is valued for its ability to enable the qualitative and quantitative methods to complement one another, thereby describing comprehensively long-term L2 changes (Liu, 2022; Pfenninger, 2022; Zheng *et al.*, 2020). Adopting a qualitative multiple-case study approach combined with a quantitative approach can explore individual trajectories, dynamic processes of language development, and their potential causes (Chang & Zhang, 2021; Li *et al.*, 2020). Furthermore, these two approaches are centered on different aspects of the questions. Specifically, quantitative analysis using models to depict the development phase facilitates the representation of broad patterns in a wider population, and it integrates with qualitative data that can identify environmental and psychological causes of changes to provide insights into emotions and cognitive processes (Muftah & Alhazmi, 2024; Pfenninger, 2022; Wirtz & Pfenninger, 2024). For instance, Li *et al.* (2023) conducted semi-structured interviews to explore specific situations, followed by structural equation modeling to depict the relationship between different components in language developmental systems.

## 3.2 Research Focus

To answer Question 2, this part identified prevalent research domains in these studies and investigated how these studies contribute to the theoretical propositions of DST.

Figure 4 shows the research focus of the reviewed articles. The research focus (n=33) in these studies is classified in nine types, including “writing” in 10 articles, “speaking” in

4 articles, "foreign language enjoyment (FLE)" in 4 articles, "others" in 4 articles, "individual differences" in 4 articles, "motivation" in 3 articles, "listening" in 2 articles, "syntax" in 2 articles. Details are shown in Appendix B1.

Most studies investigate the linguistics and language ability (n=18) with a focus on writing, speaking, listening, and syntax. Following this, cognitive focus (n=7) includes foreign language enjoyment (FLE) and motivation, while other focus (n=8) includes individual differences and others.

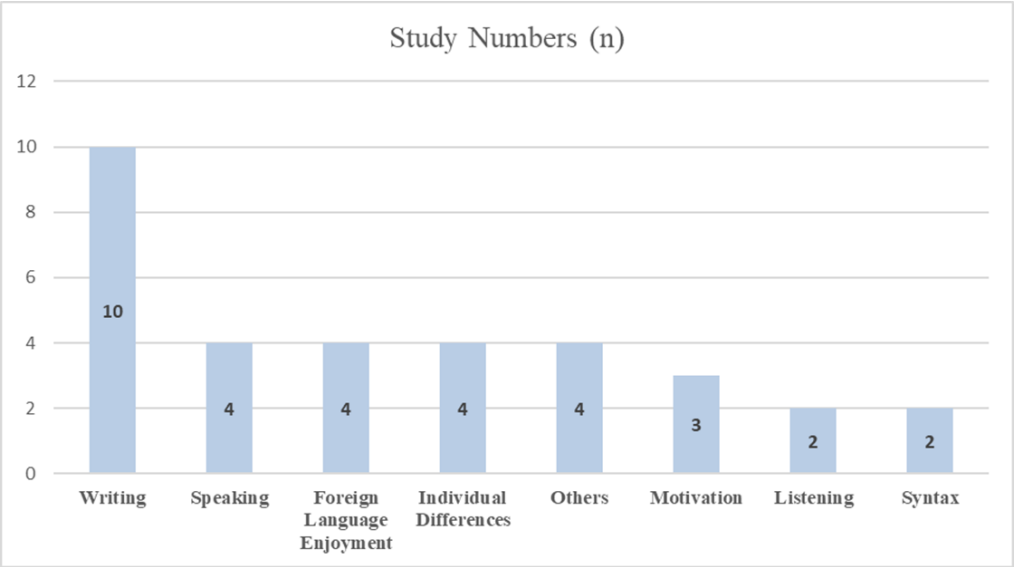


**Figure 4:** Number of research focuses

### 3.2.1 Writing (n=10)

This section summarizes the main findings of ten articles in writing and identifies their contribution to the underpinning theory of DST. They show that the variability and non-linearity, caused by continuous interactions in subsystems, are key characteristics in L2 writing development, verifying that L2 language development follows the principles of DST.

Most studies investigate the characteristics of nonlinear relationships (n=5), followed by high variability (n=3), complexity (n=2), emergent properties (n=1), and others (n=1) (Figure 5). Details are shown in Appendix B2.

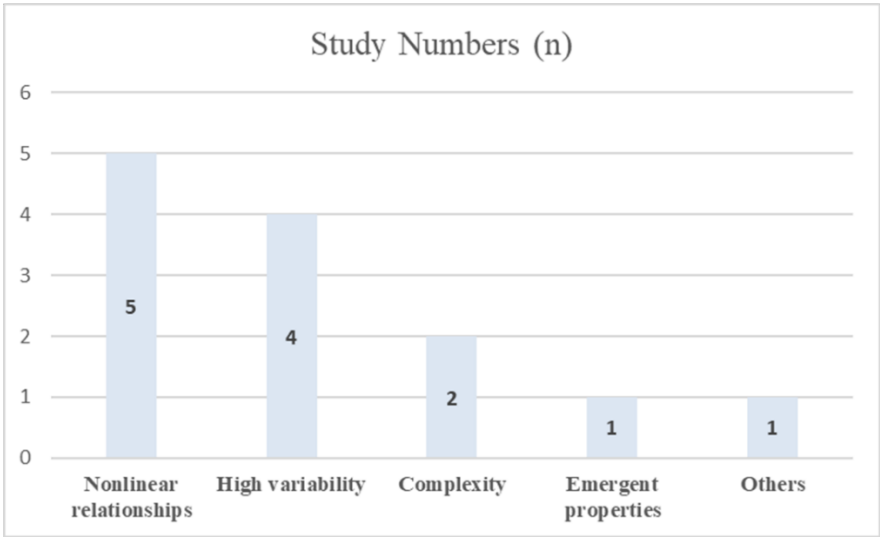


**Figure 5:** Number of key characteristics

Five studies reveal the dynamic development of second language development during the interactions among several elements (e.g., Abdi Tabari & Wind, 2025; Duan & Shi, 2024). Abdi Tabari and Wind (2025) found that the polarity and magnitude of the correlations among cohesive devices, including sentence, word complexity, and noun phrase, undergo constant changes, and their relationship varies both individually and within the group of L2 writers. Duan and Shi (2024) found that semantic transparency (MI), structure, assumed learners' proficiency, and their interactions produced significant effects on the L2 development, but function and congruency did not. Huang *et al.* (2022) found that L2+L3 learners did not develop their L2 to a lesser extent than the L2 learners did. The study investigates the dynamics of interrelated growth rates in the emergence of complexity, accuracy, and fluency in L2 English writing at secondary school, demonstrating the competition and support within language subsystems (Rokoszewska, 2022). The study presented the dynamic interaction and relationship between the developmental trajectories of using cohesive devices in writing and the writing quality (Zhang & Zhang, 2025).

Four studies reveal the high inter- and intra-individual variability in SLA (e.g., Baba & Nitta, 2021; Fogal, 2020; Zhang & Zhang, 2025). Baba and Nitta (2021) drew attention to the inter-variability development in writing task performances, finding that individuals orient and act on a task differently, resulting in divergent developmental trajectories at both the individual and group levels. The study shows that variability plays a statistically significant role in constructing authorial voice and contributes to L2 development (Fogal, 2020). Huang *et al.* (2022) found more variability in the fluency of L2 writing in L2+L3 learners over time. The results show inter- and intra-individual variability in the learner's development of global cohesion devices and their interactions (Zhang & Zhang, 2025).

Two studies reveal the complexity in SLA (Abdi Tabari & Wind, 2025; Kim *et al.*, 2024). Abdi Tabari and Wind (2025) found a positive association between two local

cohesion indices (lexical and semantic overlap) at the initial and final measurement stages. The study presents a positive link between lexical diversity and global syntactic complexity, indicating the emerging pattern of connected growth in which beginner L2 learners produce longer sentences while using a more diverse range of vocabulary (Kim *et al.*, 2024). Furthermore, Li and Zheng (2025) found that global patterns, a gradual-to-rapid trend of incremental acceleration over time, emerge from local dynamics in second-language (L2) written language development. Fogal (2024) found that system mapping as an analytic technique is effective in raising students' language awareness and developing L2 proficiency.

### 3.2.2 Speaking (n=4)

The studies show that the speaking development process is characterized by variability and non-linearity. Yu and Peng (2025) found the heterogeneity within a larger population in the dynamic evolution of L2 speaking development over time. Great differences in the initial states of WTC led to the shift in the system, revealing both idiosyncrasy and sensitivity to the initial condition characteristics of CDST (Li *et al.*, 2024). Zhou (2023) found that their WTC was accustomed to settling into one of the two attractor states (e.g., pro-talk) rather than the other (e.g., against-talk) or vice versa. Furthermore, the process is characterized as containing variable factors within a dynamic system that interact and influence each other. Multifaceted individual and contextual variables, for instance, topical interest, interlocutors, and personal motivation, interacted and influenced each other, resulting in the discrepancy of WTC in the communication context (Li *et al.*, 2024). Yu and Lowie (2020) found that the interaction between complexity and accuracy changes from competitive during the early stage to supportive at a later stage.

### 3.2.3 Foreign Language Enjoyment (FLE) (n=4)

Studies indicate that Foreign Language Enjoyment (FLE) is a dynamic and variable component that interacts with others in SLA. Elahi Shirvan *et al.* (2020) found its fluctuation between individuals across different timescales. Recent studies also investigated the interaction between Foreign Language Classroom Anxiety (FLCA) and Foreign Language Enjoyment (FLE) (Kruk *et al.*, 2023; Li *et al.*, 2020). Specifically, Kruk *et al.* (2023) found that higher Foreign Language Enjoyment (FLE) was associated with increased variability in Foreign Language Playfulness (FLP), while the greater levels of FLE or FLP predicted the diminished changes in foreign language boredom (FLB), highlighting the interplay in the developmental mechanisms of FLE, FLP, and FLB over time. Li *et al.* (2020) found that FLE exerts influence on self-perceived English proficiency and actual achievement. The study found that the negative relationship between anxiety and enjoyment varied per person, modified by four contributing factors: task execution, task layout, cognitive-linguistic factors, and performance measure (Muftah & Alhazmi, 2024).

### 3.2.4 Individual Differences (IDs) (n=4)

These studies on L2 learning variability, including personality (Jung *et al.*, 2020), cognitive styles (Kliesch & Pfenninger, 2021), and age of onset (Pfenninger, 2022), reveal that individual differences are key indicators in the SLA development process. These variables can be characterized by the ecological nature, in which various language-learning environments interact (Yung, 2025). Specifically, the results showed that extraversion was positively associated with group learning while negatively associated with individual learning (Jung *et al.*, 2020). Studies also investigate the dynamic interaction of variables in individuals and socio-factors (Jung *et al.*, 2020; Kliesch & Pfenninger, 2021; Yung, 2025). Jung *et al.* (2020) investigated the dynamicity of four learner IDs: motivation, personality, learning and cognitive styles, and working memory during the initial semester of a diachronic project. Kliesch and Pfenninger (2021) found that between-subject cognitive, socio-affective, and background variables significantly predicted both the overall level of L2 proficiency and developmental patterns. School-outside English contact is a robust predictor of learner outcomes, regardless of instruction intensity or starting time (Pfenninger, 2022).

### 3.2.5 Others (n=4)

These studies all highlight the dynamic and complex nature of SLA from different perspectives, characterized by high variability between individuals and non-linearity in development trajectories. Wirtz and Pfenninger (2024) observed that significant changes are influenced by identity and agency alongside social interaction. Li *et al.* (2022) found that output tasks, teacher guidance, group discussion, and peer assessment can influence the attractors associated with increased L2 learning experience. By exploring the relationship among componential cognitive abilities, Yu and Dong (2022) found that interpreting competence in interpreting students develops and evolves within the complex system. The results found that teachers and students, as unique systems, shaped their attitudes, beliefs, and influences through interactions with other systems. For instance, lecturers' and students' attributions to success and failure differ significantly (Alzaanin, 2023).

### 3.2.6 Motivation (n=3)

Recent studies considered motivation from a holistic, dynamic, and relational perspective. The study adopted a macro perspective, for instance, learning experience in educational institutions, to investigate the fluctuations of learners' IDs, including learners' motivation, emotions, self-efficacy, and their interaction (Piniel & Albert, 2024). In terms of motivational dynamics in interpreting learning, the findings revealed that the intra- and interindividual variability constantly evolved and interacted with a variety of factors (Liu, 2022). Zheng *et al.* (2020) argue that different aspects of multilingual and transcultural learning motivation can coexist through associations.

### 3.2.7 Listening (n=2)

The results suggest that learners demonstrated personalized intra-individual variability within their unique listening developmental process (Chang & Zhang, 2021). Li *et al.* (2023) found that the factors of foreign language listening anxiety (FLLA) included general listening anxiety and listening test anxiety, which affect the self-perceived performance. Specifically, the results showed that listening test anxiety negatively affected self-perceived performance, while general listening anxiety had a positive effect on listening test anxiety but not self-perceived performance (Li *et al.*, 2023).

### 3.2.8 Syntax (n=2)

These two studies found that the dynamic relationship in the subconstructs of syntax (Evans, 2020) and between accuracy and fluency (Evans & Larsen-Freeman, 2020), indicating the complexity and variability of the SLA, specifically in the syntax development. The continuous exposure to and interaction in English facilitates non-linear development (Evans & Larsen-Freeman, 2020).

## 4. Discussion

### 4.1 Generalizability Problem and Long Observation Period

Recent studies assert tension between group-level conclusions and individual variability. Atkinson *et al.* (2025) argue that generalizing findings from group study results to individual participants is equally problematic. Although group studies address variable interactions at single points, they fail to capture individual patterns, as no two learners follow identical developmental trajectories characterized by dynamic and non-linear (Baba & Nitta, 2021). Meanwhile, the results of dynamic features and their contributing factors are especially highly idiosyncratic, thus making them difficult to generalize to broader settings (Li *et al.*, 2024). These idiosyncratic and non-transferable characteristics challenge traditional research paradigms that seek universal rules applicable to all individuals.

To address this problem, we advocate for future studies to integrate findings regarding both general trends in group levels and actual development with variability in individual levels, thereby constructing a more holistic understanding of DST (Duan & Shi, 2024). Specifically, a rigorous longitudinal research and experimental design is capable of collecting detailed individual-level and group-level data. For instance, adopting a GMM technique is beneficial to explore the heterogeneity of oral language development (Yu & Peng, 2025). The call for rigorous procedure, including top-down metatheory, bottom-up guided explorations, top-down theory/hypothesis formation, and bottom-up empirical testing, also provides future studies with references (van Dijk *et al.*, 2024). This acknowledges that while individual cases are crucial, they are not studied separately in isolation. Instead, Multiple case studies can reveal the principles and mechanisms of language development (Atkinson *et al.*, 2025). Broader theoretical

frameworks that derive from individual cases can guide further hypothesis testing at the individual level. The iterative cycle is crucial because only after many individual cases are available and verified can general knowledge be convincing for scholars (van Dijk *et al.*, 2024). Furthermore, future studies should distinguish between product-focused and process-focused analyses because they are effective in answering distinct research questions (Atkinson *et al.*, 2025).

Meanwhile, scholars have emphasized the need to select an appropriate length in the data collection period with an increased number of measurement points, especially sufficient repeated measures (Abdi Tabari & Wind, 2025; Kim *et al.*, 2024; Li & Zheng, 2025; Yu & Lowie, 2020). These calls reveal a significant limitation in the fragmentary research design of current research. This limitation is detrimental when investigating dynamic systems, where emergent properties develop in multifaceted trajectories (Abdi Tabari & Wind, 2025). Calling for more stable and generalizable results, as highlighted by Li and Zheng (2025), aligns with the principles of DST, which posits that language patterns emerge from interactions of subsystems. Short observation periods are inadequate to capture authentic development trajectories, instead focusing on mere fluctuations, which leads to an incomplete or even misleading understanding of the evolution of SLA, for instance, failure to capture the non-linearity (Kliesch & Pfenninger, 2021). The proposals to standardize topics, genres, and lengths of writing tasks in Abdi Tabari and Wind (2025) signal a shift from purely exploratory observations to more controlled and confirmatory designs within a longitudinal framework, which aligns with the approaches for robust and comprehensive hypothesis testing (Li & Zheng, 2025). This change suggests an aim to isolate the potential variables and analyze the impact of specific factors in SLA.

Due to the potential shortcomings of research design, especially in the data collection process, previous studies are inadequate in depicting the process of interactions and evolution among different elements. Consequently, researchers are expected to explore relevant variables during a long observation period while maintaining experimental conditions to control potential factors that can affect the results. Specifically, future experimental designs can utilize a range of different timescales from moment-to-moment to long-term for dense longitudinal studies (Atkinson *et al.*, 2025; Kliesch & Pfenninger, 2021). Conducting more measurement points requires various time-series techniques and methods (Abdi Tabari & Wind, 2025). This contributes to identifying universal principles that govern DST, even if the individual differences are idiosyncratic.

### 4.2 Refine the Mechanisms of Change and Influencing Factors

Recent studies have shifted to explore the reasons and extent of their underlying mechanisms, moving beyond mere descriptions. This involves investigating the complex interplay of internal (e.g., cognitive) and external (e.g., task and context) factors. Baba and Nitta (2021) found that seemingly identical tasks yield divergent outcomes due to the

dynamic interactions and learners' changing states. The analysis of factors facilitating or inhibiting Willingness to Communicate (WTC) and their synergistic functions reveals the context dependence (Li *et al.*, 2024). Factors of subjective and social dimensions are found in both cognitive performance and Second Language Motivational Self-system (L2MSS) (Kliesch & Pfenninger, 2021; Li *et al.*, 2022).

Based on these study trends, future studies can further explore additional aspects regarding the underlying mechanisms to elaborate causative relationships among variables (Baba & Nitta, 2021; Li & Zheng, 2025). Specifically, the findings can be further repeated in experiments on similar populations, which contributes to a detailed clarification of the phenomenon revealed in both divergent and convergent results (Kliesch & Pfenninger, 2021). Besides, combining quantitative and qualitative paradigms with a focus on the existence and ongoing timing of system emergence contributes to clarifying between- and within-person developmental patterns, their more detailed mechanistic understanding, and the contributing multi-varietal sociolinguistic factors (Wirtz & Pfenninger, 2024).

## 5. Implications

By synthesizing recent studies of Dynamic System Theory (DST) in SLA, the review identifies key areas leveraging the DST perspective to improve L2 research and instruction support.

### 5.1 Implications for researchers

Based on the results of the current review, five suggestions are proposed from the perspectives of methodology, study aims, and study focus. Firstly, future research is needed to move beyond short-term studies and conduct longitudinal designs (Kim *et al.*, 2024; Li & Zhang, 2025). The evolution of a complex system cannot be fully understood by observing merely snapshots, but by collecting data over extended periods with frequent measurement points. Secondly, using mixed methods can better capture the complexity of SLA (Wirtz & Pfenninger, 2024). The value lies in the ability to complement the shortcomings of qualitative and quantitative methods (Liu, 2022; Pfenninger, 2022; Zheng *et al.*, 2020). Thirdly, the study should specify different research questions with appropriate approaches (Atkinson *et al.*, 2025) and investigate underlying mechanisms rather than revealing mere patterns. Fourthly, future research should prioritize the design for confirmatory and hypothesis-driven studies (Abdi Tabari & Wind, 2025) over exploratory studies. By conducting robust and comprehensive methodology in hypothesis testing (Li & Zheng, 2025), combined with individual-level and group-level data, more hypotheses in other experimental groups or contexts can be tested, thereby contributing to overcoming the generalizability criticisms in generating DST principles. Finally, more studies can prioritize the cognitive themes (e.g., motivation), unexplored language skills (e.g., listening and reading), and social factors (e.g., school-inside and -

outside contact). Individual differences and a wide range of social factors cannot be neglected in future studies, which require a more interdisciplinary perspective and methods for investigating the nature of DST. Furthermore, future studies can further explore how internal and external factors interact over time (Baba & Nitta, 2021) in a complex system. The affective and cognitive factors (e.g., autonomy and critical thinking) can interact in subsystems and predict the L2 learning outcomes (Kliesch & Pfenninger, 2021), thus demanding consideration in future research.

### 5.2 Implications for Educators and Practitioners

Based on the results of reviewed studies, three suggestions are proposed for pedagogical approaches in the classroom. Firstly, future educators and practitioners should consider language teaching as a complex system where motivation (e.g., Li *et al.*, 2024), foreign language enjoyment (e.g., Kruk *et al.*, 2023), and other cognitive factors may interact to influence L2 performance. Multiple beneficial factors (e.g., positive motivations) may act as a catalyst and contribute to successful L2 learning when a supportive learning environment is cultivated. Secondly, future educators and practitioners need to embrace variability in individual learners and acknowledge the nonlinearity in developing different language skills. A range of sub-systems may interact to facilitate the process of SLA in specific stages (e.g., Rokoszewska, 2022). Individual differences should be taken into account so that appropriate pedagogical strategies can be adapted to learners and facilitate the learning process. Thirdly, persistent teaching strategies and accurate evaluative testing need to be explored in the future to evaluate the language development in more holistic and long-term dimensions. Future educators and practitioners can enhance learners' language development by leveraging every potential cognitive and social benefit in pedagogical instructions, such as providing regular practice opportunities (Kim *et al.*, 2024).

## 6. Limitations and Conclusion

Through analyzing the study focus, methodology, and contributions towards the DST, this study conducts a systematic review of Dynamic Systems Theory (DST) applications in Second Language Acquisition (SLA) in empirical studies published between 2020 and 2025, addressing fragmentation in this field. Our analysis revealed the prevalence of multi-layered and methodologically diverse designs as well as debates regarding the generalizability of results and the ambiguity of underlying mechanisms.

This research contributes to a focused and contemporary synthesis in the critical examination of DST's application in SLA, advocating for more rigorous research approaches and integrative research design. By providing a critique and highlighting the challenges in recent studies, this review serves as a critical reference for researchers and educators, aiming to foster a more unified and theoretically robust understanding of DST.

Two limitations exist in the present review. The selected articles were from SSCI journals, which ensure exceptional quality and a high rate of citations. Nevertheless, it may lead to one-sidedness of the results. Future studies can expand the literature span to more resources, such as book chapters, conference papers, and journal articles indexed by Scopus, Eric, etc. (Zhang & Zou, 2022). By collecting more relevant studies, a broader range of study themes and methodologies can be synthesized in the analysis, thereby contributing to the comprehensiveness and objectivity of the review. Moreover, this study focuses on themes and methods, setting aside the experimental details, such as participants' ages and groups. These factors may explain the choices of methods and the potential for discussion of theory. Thus, future studies can explore more information regarding experiment design.

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**Conflict of Interest Statement**
The author declares no conflicts of interest.

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**Appendix A1:** Paper Reviewed in the Analysis

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## **Appendix A2:** Coding schema for the selected studies

| **Dimentions** | **Coding types** | **Subtypes** | **Definition of subtypes** | **Sources** |
|---|---|---|---|---|
| Research Focus | Themes | 1. Language Ability and Linguistics: Writing, speaking, listening and syntax | Studies that reported themes of language ability or linguistics, e.g., listening, speaking, reading, writing, pragmatic, syntax | Adapted from Shadiev and Yu (2022) |
| | | 2. Cognitive: Foreign Language Enjoyment (FLE), Motivation | Studies that reported cognitive themes, e.g., motivation | |
| | | 3. Others: Individual Differences and others | Studies that reported themes other than the above two | |
| Key Characteristics | Characteristics | 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 | Adapted from Atkinson et al. (2025) |
| | | 2. High variability | Language use varies across speakers, contexts, and situations, reflecting the adaptability of language | |
| | | 3. Emergent properties | Language features like grammatical patterns arise from component interactions | |
| | | 4. Complexity | Language has hierarchical organization, self-similarity across levels, and sensitivity to initial conditions | |
| | | 5. Others | Characteristics other than the above four | |
| Research Method | Methods | 1. Quantitative | Studies that utilized quantitative methods, including questionnaire surveys and test | Zou et al. (2022) |
| | | 2. Qualitative | Studies that utilized qualitative methods, e.g., interviews, class observation, log data | |
| | | 3. Mixed | Studies that utilized both quantitative and qualitative methods, e.g., Closed-ended questionnaires + interviews | |

## **Appendix B1**

| Table B1 | | | |
|---|---|---|---|
| Research Focus | sub-category | Authors | Study Numbers (n) |
| Language Ability/Linguistics | Writing | Abdi Tabari & Wind (2025), Baba & Nitta (2021), Duan & Shi (2024), Fogal (2020), Fogal (2024), Huang et al. (2022), Kim et al. (2024), Li & Zheng (2025), Rokoszewska (2022), Zhang & Zhang (2025) | 10 |
| | Speaking | Li et al. (2024), , Yu & Lowie (2020), Yu & Peng (2025), Zhou (2023) | 4 |
| | Listening | Chang & Zhang (2021), Li et al. (2023), | 2 |
| | Syntax | Evans (2020), Evans & Larsen-Freeman (2020) | 2 |
| Cognitive | Foreign Language Enjoyment (FLE) | Elahi Shirvan et al. (2020), Kruk et al. (2023), Li et al. (2020), Muftah & Alhazmi (2024) | 4 |
| | Motivation | Piniel & Albert (2024), Liu (2022), Zheng et al. (2020) | 3 |
| Others | Individual Differences | Jung et al. (2020), Kliesch & Pfenninger (2021), Pfenninger (2022), Yung (2025) | 4 |
| | Other variables | Alzaanin (2023), Li et al. (2022), Wirtz & Pfenninger (2024), Yu & Dong (2022) | 4 |

## Appendix B2

| Table B2 | | |
|---|---|---|
| Key Characteristic | Authors | Study Numbers (n) |
| Nonlinear relationships | Abdi Tabari & Wind (2025), Duan & Shi (2024), Huang et al. (2022), Rokoszewska (2022), Zhang & Zhang (2025) | 5 |
| High variability | Baba & Nitta (2021), Fogal (2020), Zhang & Zhang (2025) | 3 |
| Emergent properties | Li & Zheng (2025) | 1 |
| Complexity | Abdi Tabari & Wind (2025), Kim et al. (2024) | 2 |
| Others | Fogal (2024) | 1 |

## Appendix C

| Table C1 | | |
|---|---|---|
| Methods | Authors | Numbers |
| Quantitative | Abdi Tabari & Wind (2025), Baba & Nitta (2021), Elahi Shirvan et al. (2020), Evans (2020), Evans & Larsen-Freeman (2020), Huang et al. (2022), Jung et al. (2020), Kim et al. (2024), Kliesch & Pfenninger (2021), Kruk et al. (2023), Li & Zheng (2025), Piniel & Albert (2024), Rokoszewska (2022), Yu & Lowie (2020), Yu & Dong (2022), Yu & Peng (2025), Duan & Shi (2024) | 17 |
| Qualitative | Li et al. (2022), Li et al. (2024), Yung (2025), Zhang & Zhang (2025), Zhou (2023) | 5 |
| Mixed-method | Chang & Zhang (2021), Fogal (2020), Fogal (2024), Li et al. (2020), Li et al. (2023), Liu (2022), Muftah & Alhazmi (2024), Pfenninger (2022), Wirtz & Pfenninger (2024), Zheng et al. (2020) | 10 |