Complex Dynamic Systems Theory in Second Language Learning and Teaching: A Textometric Review from 2008 to 2022

Huixian Li, Yongyan Zheng*

College of Foreign Languages and Literature, Fudan University, China

Abstract

Complex Dynamic Systems Theory (CDST) has significantly reshaped our understanding of second language learning and teaching across the micro, meso, and macro levels for several decades since its systematic introduction by Larsen-Freeman and Cameron (2008). This study conducts a comprehensive review of empirical research on second language learning and teaching within the framework of CDST from 2008 to 2022. Textometric analysis, a computer-supported qualitative method for textual analysis, was employed to conduct the review by using the IRAMUTEQ software. A total of 198 publications were identified, leading to the emergence of three prominent research themes: research on the language system, research on the second language learner and learning, and research on the second language teacher and teaching. The chronological trends and distinguishing features of the three research themes were discussed against a mainstream model of language learning and teaching at the micro, meso, and macro levels (The Douglas Fir Group, 2016). The findings of this review hold the potential for enlightening future research endeavors in this field.

Keywords: *Complex Dynamic Systems Theory, Second Language, Literature Review, Textometry*

Introduction

Since Larsen-Freeman introduced the Complex Dynamic Systems Theory (hereafter CDST) into Second Language (L2) research (Larsen-Freeman, 1997; Larsen-Freeman & Cameron, 2008), fundamental questions that have driven research on L2 learning and teaching – how L2 learners deploy their verbal and non-verbal resources at the *micro level* to engage in specific multilingual contexts at the *meso level*, while being guided by the overarching ideology towards language use and learning at the *macro level* (The Douglas Fir Group, 2016) – have undergone paradigm shifts across all levels over the past decades. To gain an understanding of how CDST has reconceptualized these fundamental questions, it is an endeavor at the opportune time, marking the 15th year since its systematic introduction (Larsen-Freeman &

Cameron, 2008), to synthesize the current CDST-inspired empirical studies, chronicle the developmental trends, and discuss their current status in L2 learning and teaching. For this purpose, the present study reviews the existing CDST-inspired L2 research from 2008 to 2022 to discuss their significance against a mainstream model of language learning and teaching at the micro, meso, and macro levels (The Douglas Fir Group, 2016).

CDST through an Analytical Lens of a Multilevel L2 Model

In what follows, we would discuss how CDST provides revolutionary perspectives on L2 learning and teaching across the micro, meso, and macro levels, thus justifying the multilevel model (The Douglas Fir Group, 2016) as an appropriate analytical lens for this review.

At the micro level, CDST views languages and language learners as complex and dynamic systems consisting of multiple components that interconnect and interact with each other to generate some overall states at a specific moment (Larsen-Freeman & Cameron, 2008). Regarding the language system, this perspective rejects the reductionist view of reducing the complex situation to a universal principle that removes all the "noises" in a "grand-sweep" way (Lowie & Verspoor, 2015). Instead, it embraces the belief that language is not fixed or closed but is an ever-developing and open system where patterns emerge from the continuous self-organization among multiple components at multiple scales (Larsen-Freeman, 2015). Rather than being an additive and linear process, language learning is a moment-to-moment effort that constantly feeds into the next condition in a cyclic and iterative fashion (Larsen-Freeman, 2015). There is no target endpoint (Larsen-Freeman, 1997). The growth and decline, acquisition and attrition are equally valuable (de Bot & Larsen-Freeman, 2011). Variability is not merely measurement error but is informative about development (Larsen-Freeman & Cameron, 2008; Verspoor, Lowie, & de Bot, 2021; Verspoor & de Bot, 2021). With regard to the learner system, this perspective corroborates the cognitivism by emphasizing that learners are not only passive recipients of external input. Instead, they actively engage in language learning, and exert a more agentive, robust, and empowered influence over language use and learning by self-organizing their cognitive, affective, interactional, social, political, neural, and semiotic resources (Larsen-Freeman, 2012) and soft-assembling language patterns on given occasions (Thelen & Smith, 1994).

At the meso level, CDST refuses the behaviorism that regards learning and teaching as a uni-directional and linear process from the teacher to the learner (Larsen-Freeman, 2016), or the reductionism which assumes language learning as happening in static isolation or an ideal vacuum with the context as merely a backdrop (Larsen-Freeman & Cameron, 2008). CDST orients for an ecological and holistic perspective recognizing that language learning and teaching are situated in the temporal and spatial contexts which are nested in a hierarchical fashion at different scales (Larsen-Freeman, 2016, 2018). In other words, language is socially constructed (Ellis & Larsen-Freeman, 2006). The language learners, teachers, other stakeholders, and the context are co-adaptive and reciprocally connected systems (Larsen-Freeman & Cameron, 2008), constantly giving and receiving feedback to and from each other (Hiver & Al-Hoorie, 2020). Thus, changes in one system would lead to changes in another (Larsen-Freeman, 2016). Crystalized patterns of behavior or language usage emerge from the co-adaptation of the community at multiple timescales (Larsen-Freeman & Cameron, 2008).

At the macro level, CDST challenges the native/target language standards and the language

teleology – the belief that language learning should aim for an endpoint that meets the native speaker standards (Larsen-Freeman, 2006a). It also denies the linear developmental ladder along which learners climb stage by stage till reach full proficiency (Larsen-Freeman, 2006b). On the contrary, CDST recognizes the existence of variability and fluctuation in the language developmental trajectories, and holds the belief that not all learners are obligated to adhere to the native speaker standards (Larsen-Freeman, 2018), especially those that are shaped by the essentialist language ideology (Ortega, 2017, as cited in Larsen-Freeman, 2018). This also reveals CDST researchers' rejection of a homogeneous society to embrace a multilingual world, where multiple languages, varieties, and dialects are recognized and their accompanied identities are valued (Larsen-Freeman, 2018). This CDST ideology on language could be reflected in learning and teaching, for example, by designing language assessments that acknowledge learners' developing capacity rather than their static competence (Larsen-Freeman, 2015), avoiding the "one-size-fits-all" approach to set the same learning goal in the same classroom composed of learners from various linguistic backgrounds (Larsen-Freeman & Tedick, 2016, p. 1339), and even more macro-level language management and planning.

These revolutionary perspectives of CDST have ignited growing research interest in L2 learning and teaching across the micro, meso, and macro levels (see e.g. Fogal, 2022; Hiver, Al-Hoorie, & Evans, 2022), spurring the impetus of this review to synthesize where the current state of CDST-inspired empirical research is and to inform where future research to move. This review distinguishes itself from the previous discussion or systematic/scoping reviews on CDST research (e.g. Fogal, 2022; Hiver, Al-Hoorie, & Evans, 2022; Han, Kang, & Sok, 2023; Larsen-Freeman, 2018) in that it situates the current CDST studies against a more global picture of L2 teaching and learning research at the micro, meso and macro levels, that is, the Douglas Fir Group (2016) model (hereafter the DFG model), in lieu of discussing CDST research per se or in a specific domain. A secondary purpose of this review is to exploit the textometric method as a quantitative tool to complement the traditional qualitative analysis by allowing general themes to emerge in a data-driven and bottom-up fashion. This approach is invulnerable to human bias and capable of foregrounding those underlying patterns that usually go unnoticed by human coding (Ramos, do Rosário Lima, & Amaral-Rosa, 2019). The review is guided by the following research questions:

RQ1: What themes emerge from the CDST-inspired L2 research?

RQ2: What are the chronological trends of each theme in the CDST-inspired L2 research?

RQ3: What is the current status of each theme in the CDST-inspired L2 research?

Methodology

Literature Identification and Screening

This review follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page, McKenzie, Bossuyt et al., 2021) to identify and screen articles (Figure 1). Firstly, five databases were searched: Web of Science, Scopus, Education Resources Information Center (ERIC), Linguistics and Language Behavior Abstracts (LLBA), and PsycINFO (In'nami & Koizumi, 2010; Oswald & Plonsky, 2010; Plonsky & Brown, 2015), by using keyword combinations: ("foreign language" OR "second language" OR "linguistic" OR "L2") AND ("Complex Dynamic Systems Theory" OR "complexity theory" OR "dynamic systems" OR "complex dynamic systems" OR "CDST" OR "DST" OR "dynamic

development" OR "complex adaptive systems theory" OR "chaos theory"). Searching was conducted within three research areas: linguistics (language), education, and psychology. The publication time was set from January 2008 to December 2022, as marked by Larsen-Freeman and Cameron's (2008) seminal work. Papers were restricted to empirical articles published in English, excluding book chapters, theoretical papers, reviews, conference reports, or others. A total of 2761 entries were downloaded from the databases. Then, these identified entries were reviewed by two researchers who are expert in applied linguistics to determine if they meet the criteria of being second language research, and being framed within CDST. By focusing on second language research, we did not intend to make a separation between second language and foreign language, nor did we reject research like first language attrition accompanying L2 development, or the development of languages in addition to the second language. In this review, we used "second language research" as an umbrella term for research on additional languages. Controversial entries were discussed until full agreement was reached (Kappa = 0.82, $p < .01$). Finally, backward searching has added two paper to the list, ending up with a total of 198 papers (see supplementary materials).

Figure 1
PRISMA Flow Diagram for Identification and Screening Procedures
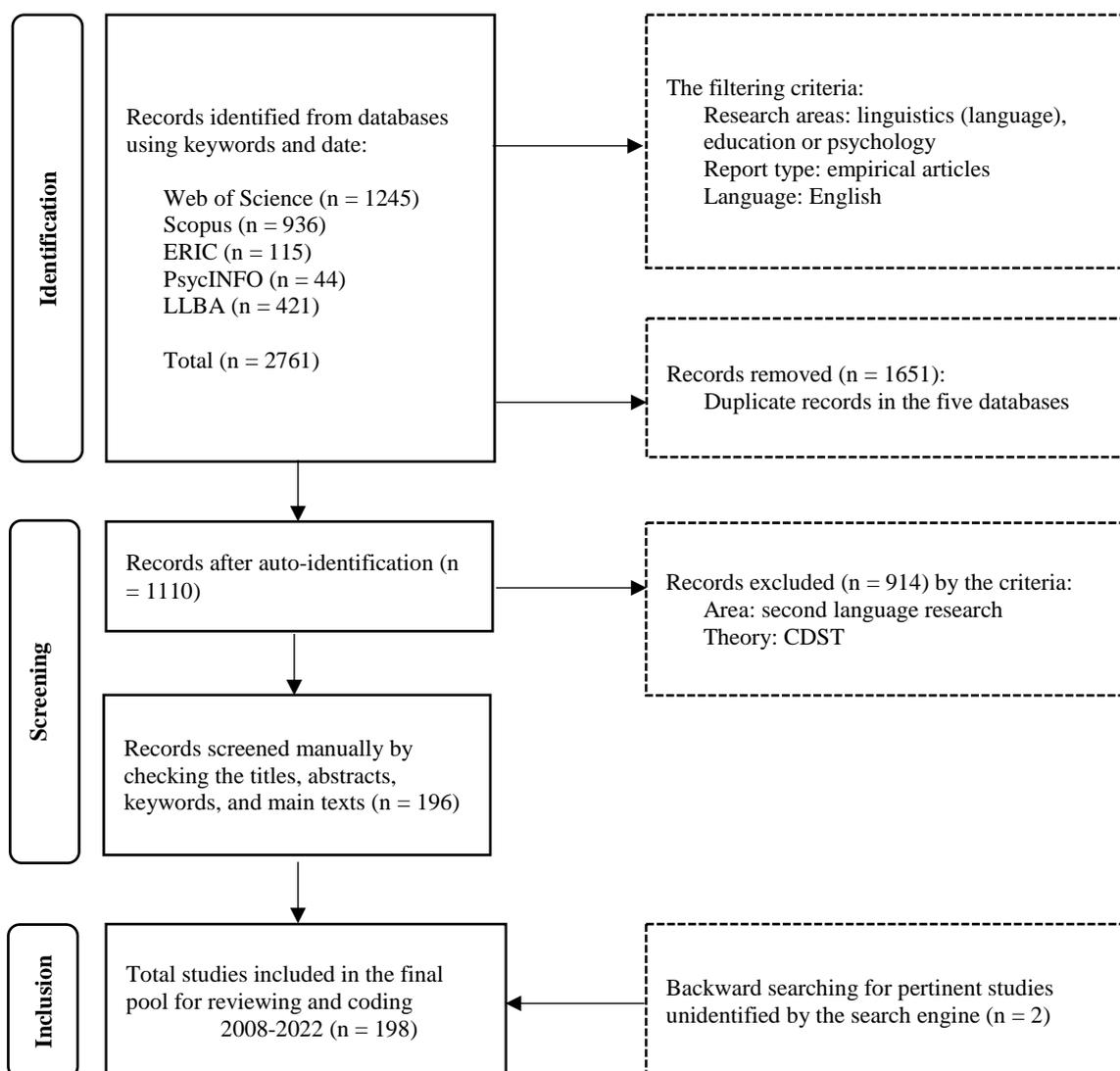
Textometry as a Method for Literature Review

Textometry is a computer-supported qualitative method for conducting textual analysis (Ramos, do Rosário Lima, & Amaral-Rosa, 2019). It relies on word counts and statistical analysis to conduct data referencing and contextual comparison (Pincemin & Marchand, 2022). In contrast to other textual-analysis methods, textometry effectively maintains a balance between quantitative and qualitative approaches (Pincemin & Marchand, 2022). On the one hand, it shares merits with text mining (Feld & Sanger, 2006), allowing for statistically supported summaries, extractions, and visualizations. On the other hand, it enjoys the advantage of close annotation and thick description, allowing for a rich and detailed view of the text (Pincemin & Marchand, 2022). Compared to the traditional qualitative analysis conducted by human beings, it is not only a robust method capable of handling large volumes of texts with the assistance of quantitative calculation (Pincemin & Heiden, 2008), but also a powerful tool to detect patterns that would otherwise be obscured from naked eyes.

The textometric analysis was carried out using the software *Interface de R pour les Analyses Multidimensionnalles de Textes et de Questionnaires* (Interface of R for Multidimensional Text and Questionnaire Analysis, hereafter IRAMUTEQ) (http://www.iramuteq.org). It was developed in French in 2009 (Camargo & Justo, 2013) and was later used to conduct discursive textual analysis (Ramos, do Rosário Lima, & Amaral-Rosa, 2019) and textometric review (e.g. Fonseca, Abreu, Guerreiro, & Barros, 2022) in languages other than French. It allows for the bottom-up emergence and visualization of main themes from the corpus texts. The following procedures guided the analysis:

Corpus Building and Cleaning

The abstracts of studies identified from the PRISMA procedure were retrieved to build the textual corpus. The corpus was cleaned by removing the messy information (e.g. citations), checking the spelling of words, ensuring the consistency of expressions and abbreviations, and replacing the unrecognizable punctuation (e.g. quotes, hyphens, percentages, asterisks, etc.) with the underscores recognizable for IRAMUTEQ. In addition, some formulaic academic expressions were made into single forms by connecting the words with underscores so as to avoid the false positivity in the interpretation of word frequency, as exemplified by differentiating the word *English* in *English-as-a-Foreign-Language* and *Languages-Other-Than-English*. Then, we checked and modified the English dictionary in IRAMUTEQ, allowing for a more authentic reflection of the academic texts. For example, the word *show* was recognized as a noun in IRAMUTEQ's default English dictionary. But it is more frequently used as a verb in academic abstracts in this review.

Basic Textual Statistics

IRAMUTEQ identifies the number of texts, the frequency of words (types and tokens), hapax legomenon (words occur only once), active (content) words, supplementary (function) words, as well as root-based lemmas (stems). It should be noted that IRAMUTEQ conducts its analysis by segmenting the corpus into units based on text length, typically 40 words per unit by default. These units are considered as the context of words (Lavissière, Sohier, & Lavissière, 2020). In this review, we have chosen to use the length of each abstract (approximately 180 words) as the primary analysis unit, as it better reflects the word context within individual studies.

Descending Hierarchical Classification (DHC) and Factorial Correspondence Analysis (FCA)
The Descending Hierarchical Classification (DHC) allows for detecting the emerging themes in the textual corpus. These themes are derived from word clusters. Specifically, texts are classified into homogenous clusters based on the chi-squared (x^2) correlation between the cluster and the frequency of the content words (Bart, 2011; Fonseca, Abreu, Guerreiro, & Barros, 2022). Those units containing similar sets of content words would be classified into the same cluster. Thus, different research themes would emerge. This classifying procedure is called the Reinert method (Reinert, 1983). The emerging themes (clusters) are considered as the lexical worlds or semantic contexts (Reinert, 1990), as they represent cognitive "common places" that authors tend to gravitate toward (Reinert, 1993). DHC is distinguished from the traditional qualitative categorization in that the themes are emergent from a data-driven approach and attested by the x^2 significance, thus avoiding human biases and foregrounding themes that would otherwise be invisible from manual coding (Ramos, do Rosário Lima, & Amaral-Rosa, 2019). The Factorial Correspondence Analysis (FCA) visualizes the distances of each cluster in a Cartesian plane (Ramos, do Rosário Lima, & Amaral-Rosa, 2019).

Data Analysis
To address the first research question, we conducted DHC and FCA on all the abstracts in the corpus to detect the main themes in the 198 CDST research. Analysis was performed on content words except for the verbs (e.g. show, reveal, conduct) for the purpose of obtaining a more accurate picture of the research themes. To address the second research question, first we conducted a manual check and made necessary adjustments to the studies that had been automatically categorized into each theme. Then, we visually depicted the chronological trends of the current research of CDST, including both the overall number of publications and the distribution of publications in each theme. To address the third research question, we made qualitative interpretations on studies in each theme to elucidate their current status in depth.

Findings and Discussion
Themes Emerging from CDST-Inspired L2 Research
Table 1 provides an overview of the descriptive statistics for the abstract corpus. Three clusters emerged from the results of DHC and FCA, successfully classifying 193 out of 198 abstracts (97.47%). In Figure 2, each cluster is visually represented by different colors, and the distances between them are visually depicted. The greater the distance between words or clusters, the more dissimilar they are from each other. The size of words in Figure 2 corresponds to their x^2 value associated with the respective cluster. Larger word sizes indicate higher x^2 values, revealing a stronger association between the word and that cluster. Table 2 shows the top 30 most impacted words (words with the highest x^2) in each cluster.

Table 1

Preliminary Analysis after Lemmatization

Index	Total number
Number of texts	198
Number of occurrences (tokes)	34207
Number of lemmas	3260
Number of forms (types)	4136
Number of active forms	2344
Number of supplementary forms	389
Number of hapax legomenon	1422
	(4.16% of occurrences, 43.62 % of forms)
Number of clusters	3
193 texts classified on 198 (97.47%)	

Figure 2

DHC and FCA Representation of Impacted Words in Each Cluster

Table 2

The Top 30 Most Impacted Forms in Three Clusters

rank	cluster 1		cluster 2		cluster 3	
	form	x^2	form	x^2	form	x^2
1	development	34.33**	willingness to communicate	24.11**	practice	32.51**
2	lexical	33.50**	anxiety	21.63**	teacher	24.47**
3	longitudinal	25.90**	foreign	20.05**	education	20.40**
4	L2	25.37**	classroom	19.85**	context	17.35**
5	word	24.06**	enjoyment	18.96**	interview	16.32**
6	accuracy	23.56**	emotion	16.78**	professional	15.70**
7	variability	23.43**	idiodynamic	15.13**	educator	15.70**
8	syntactic	20.40**	factor	14.60**	agency	13.66**
9	general	18.67**	positive	14.23**	informal	13.66**
10	fluency	15.98**	communication	11.98**	place	12.22**
11	regression	15.70**	stable	11.87**	semi-structured	10.96**
12	sentence	15.70**	interlocutor	11.66**	experience	10.87**
13	trend	15.70**	variable	11.33**	effective	10.26**
14	construction	14.22**	participant	11.12**	technology	9.65**
15	essay	13.66**	turn	10.41**	secondary	9.54**
16	linear	13.66**	temporal	9.91**	conceptual	9.54**
17	individual differences	13.35**	class	9.52**	external	9.54**
18	L1	12.32**	conversation	9.28**	component	8.92**
19	intra-individual	12.22**	self-ratings	9.28**	educational	8.34**
20	usage-based	11.65**	self-rated	9.28**	contribution	8.34**
21	consistent	11.65**	moment-to-moment	9.28**	identity	7.72**
22	text	11.42**	pedagogical	8.72**	difficulty	7.72**
23	proficiency	10.87**	recent	8.38**	unique	7.72**
24	clause	9.65**	nature	8.23**	practical	7.72**
25	exposure	9.65**	situational	8.12**	COVID 19	7.68**
26	usage	9.65**	personality	8.12**	awareness	7.68**
27	path	9.65**	affective	8.08**	author	7.68**
28	experiment	9.65**	female	7.76**	rich	7.68**
29	early	9.65**	timescales	7.73**	interpretive	7.68**
30	Dutch	9.65**	negative	7.73**	conclusion	7.68**

Note. $^*p < .05,$ $^{**}p < .01$

    As the results show, Cluster One is related to CDST research on the language systems (e.g. Baba & Nitta, 2014; Polat & Kim, 2014; Spoelman & Verspoor, 2010; Verspoor, Lowie & van Dijk, 2008; Yu & Lowie, 2020; Zheng, 2016). The most impacted forms in this cluster include but not limited to *development* ($x^2 = 34.33$, p < 0.01), *lexical* ($x^2 = 33.50$, p < 0.01), *longitudinal* ($x^2 = 25.90$, p < 0.01), *word* ($x^2 = 24.06$, p < 0.01), *accuracy* ($x^2 = 23.56$, p < 0.01), *variability* ($x^2 = 23.43$, p < 0.01), *syntactic* ($x^2 = 20.40$, p < 0.01), *fluency* ($x^2 = 18.67$, p < 0.01), *sentence*

($x^2 = 15.70$, p < 0.01), *proficiency* ($x^2 = 10.87$, p < 0.01), *clause* ($x^2 = 9.65$, p < 0.01). For example, Zheng (2016) examined the one-year development of 15 EFL learners' lexical use and found an increasing trend for lexical diversity and sophistication, a flattening trend for lexical density, and a U-shaped curve for lexical bundles. In another study, Yu and Lowie (2020) examined the oral language development of 10 EFL learners over the course of a semester. Their findings revealed non-linear and dynamic patterns of development, as well as a complex interplay between complexity and accuracy. This interplay evolved from a competitive relationship during the early stages to a more supportive relationship in the later stages of language development.

Cluster Two is related to CDST research on the L2 learner and learning (e.g. Dewaele & Pavelescu, 2019; Han & Hiver, 2018; Kiss & Pack, 2022; MacIntyre & Wang, 2021; Yu, Lowie, & Peng, 2022; Zheng, Lu, & Ren, 2020). The most impacted forms in this cluster include but not limited to *willingness to communicate* ($x^2 = 24.11$, p < 0.01), *anxiety* ($x^2 = 21.63$, p < 0.01), *enjoyment* ($x^2 = 28.96$, p < 0.01), *emotion* ($x^2 = 16.78$, p < 0.01), *affective* ($x^2 = 8.08$, p < 0.01). For example, Dewaele and Pavelescu (2019) investigated the changes in two high-school English learners' willingness to communicate and its relationship with enjoyment and anxiety. They found that various interacting learner-internal and external factors could influence their emotions, which further influences their willingness to communicate in dynamic and idiosyncratic ways. Yu, Lowie and Peng (2022) portrayed 176 EFL learners' motivational development over two semesters. They observed both a decreasing trend and an increasing trend for learners' ideal L2 self and ought-to L2 self. They also found three learner profiles: learners with weak ideal L2 self, ought-to L2 self, and learning experience; learners with weak ideal L2 self and ought-to L2 self, but moderate learning experience; and learners with moderate ideal L2 self and learning experience, but weak ought-to L2 self.

Cluster Three is related to CDST research on the L2 teacher and teaching (e.g. Aslan, 2015; Fogal & Koyama, 2022; Smith & King, 2017; Sun & Zhang, 2022; Sak, 2022). The most impacted words in this cluster include but not limited to *practice* ($x^2 = 32.51$, p < 0.01), *teacher* ($x^2 = 24.47$, p < 0.01), *education* ($x^2 = 20.40$, p < 0.01), *context* ($x^2 = 17.35$, p < 0.01), *professional* ($x^2 = 15.70$, p < 0.01), *educator* ($x^2 = 15.70$, p < 0.01), *agency* ($x^2 = 13.66$, p < 0.01), *educational* ($x^2 = 8.34$, p < 0.01), *identity* ($x^2 = 7.72$, p < 0.01), *practical* ($x^2 = 7.72$, p < 0.01), *awareness* ($x^2 = 7.68$, p < 0.05). For instance, Sun and Zhang (2022) investigated teachers' cognition and practice about focus-on-form instruction of the English language by focusing on two novice teachers and two experienced teachers. They found that all teachers favored focus-on-form instruction but the two novice teachers faced complex challenges in implementing focus-on-form instruction in their actual teaching practices. Sak (2022) examined the dynamic changes in two Turkish EFL teachers' motivation during online classes over two weeks. They found substantial changes within participants and differences across participants in their motivation, originating from a wide range of learner-related, course-related, and personal factors.
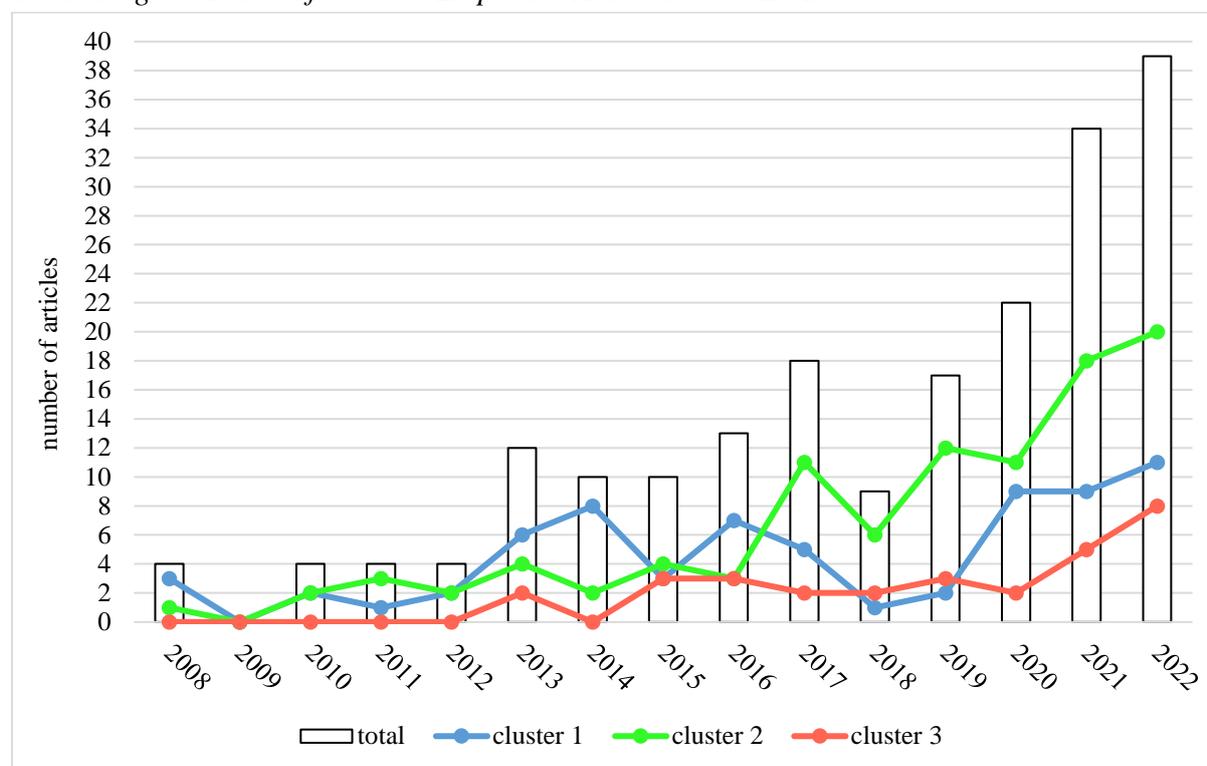
The Chronological Trend of each Theme in CDST-Inspired L2 Research
The chronological trends of the number of empirical studies on CDST from 2008 to 2022 is shown in Figure 3. The bar graph represents the number of all publications, which clearly

shows an increasing interest in the area. The first decade (from 2008 to 2017) saw a gradual increase with fluctuation. In the recent five years (from 2018 to 2022), the number of publications surged.

Figure 3

Chronological Trend of Current Empirical Research on CDST

Built upon the clusters elicited from DHC and FCA, the colored lines show the chronological trends of each research theme. The blue line represents research on the language systems. This theme of research has arisen researchers' interest since CDST's inception, gained popularity between 2013 and 2019 with some fluctuation, and revitalized again since 2020. The green line represents research on the L2 learner and learning. This theme of research increased gradually over the first half period, soared since 2017, and reached a peak in 2022, indicating a growing interest in this theme in recent years. The red line represents research on the L2 teacher and teaching. This theme of research has attracted researchers' attention quite late, with a majority of studies being published after 2015. This theme is underexplored as compared with the other two themes.

Current Status of Each Theme in CDST-Inspired L2 Research

The three themes emerging from the textometric analysis would serve as a framework to guide our qualitative interpretation, anchoring the current status of CDST research in three main areas: the language system, L2 learner and learning, and L2 teacher and teaching. In this section, each of these themes will be discussed in detail and supported by relevant examples.

Language Systems

Research on the language systems generally targets at profiling the language developmental

trajectories and detecting the interacting processes of different subsystems (e.g. lexical and clausal subsystems). These studies follow two directions.

One strand of research tracks a small number of cases to elucidate their language developmental paths in depth (e.g. Baba & Nitta, 2014; Polat & Kim, 2014; Spoelman & Verspoor, 2010; Verspoor, Lowie & van Dijk, 2008; Yu & Lowie, 2020; Zheng, 2016), built upon the CDST assumption that language trajectories relying on group average results cannot be generalized to individual trajectories and vice versa (Larsen-Freeman, 2006b). For example, Verspoor, Lowie and van Dijk (2008) observed the writing development of an advanced-level learner over three years. They found that during the first observation point, lexical Type-Token Ratio and sentence length showed a positive correlation but turned into a negative correlation during later points. Spoelman and Verspoor (2010) tracked a Finnish learner over three years with 54 writing samples to examine the accuracy and complexity subsystems. They found the two subsystems developed in non-linear ways, characterized by peaks and regressions, interaction, and competition. Baba and Nitta (2014) traced two EFL university learners over a school year at weekly intervals. Their analysis revealed that both learners experienced at least one phase shift in their writing fluency, as identified through indicators such as sudden leaps, anomalous variance, divergence, and qualitative changes.

A more recent strand of research draws upon learner corpus to crystalize group patterns shared by a small group of homogeneous learners in a bottom-up fashion (e.g. Baba & Nitta, 2021; Gui, Chen, & Verspoor, 2021; Huang, Steinkrauss, & Verspoor, 2021, 2022; Peng, Lowie, & Jager, 2022; Zhang, Zhang, & Zhang, 2022). While exploring intra-individual variability highlights changes and differences, overamplification of it might blur a more global picture of crystalized patterns. Though generalization and prediction are not the targets of CDST (Larsen-Freeman & Cameron, 2008), it does not mean no global patterns could be detected (Molenaar, 2015). In lieu, CDST believes that certain shared patterns would emerge from language use (Larsen-Freeman & Cameron, 2008). For example, Peng, Lowie and Jager (2022) tracked nine Chinese university learners of English over 10 months, and examined their syntactic complexity development. They found five patterns of developmental trajectories regarding the slope (rate), intercept (initial condition), and autocorrelation (dependency on the previous condition) of syntactic complexity, thus unraveling commonalities in learners' developmental processes that transcended the individual heterogeneity. Huang, Steinkrauss and Verspoor (2021) operationalized the degree of variability in the development of 22 college-level English learners. Their research indicated that as learners diversified their writing strategies, they ultimately made more gains in their writing skills. Their findings provided supportive evidence asserting variability as a signal of improvement at the group level.

L2 Learner and Learning

CDST has brought a revolutionary view on L2 learner and learning that fully recognizes learners' agency in the learning process (Larsen-Freeman, 2012, 2019). Thereby, a large volume of research has dedicated to investigating language learners as agentive, cognitive, affective, and embodied beings. Such research generally follows two directions.

One branch of studies attempts to untangle the interaction and developmental paths of learner-internal factors in the learning process (e.g. Dewaele & Pavelescu, 2019; Han & Hiver, 2018; Kiss & Pack, 2022; MacIntyre & Legatto, 2011; MacIntyre & Wang, 2021; Yu, Lowie,

& Peng, 2022; Zheng, Lu, & Ren, 2020). For example, MacIntyre and Wang (2021) employed the idiodynamic method to investigate the moment-to-moment changes in three learners' willingness to communicate. They found that emotions and communicative intentions influenced the underlying dynamic patterns of learners' willingness to communicate within a communication event. Zheng, Lu and Ren (2020) tracked 15 Chinese university-level students engaged in learning L2 English and L3 Spanish over a period of 1.5 years with a Q methodology. They found two types of changing motivational profiles among learners. One motivational profile was dominated by a translingual and transcultural orientation and developed towards either more constitutive ideal multilingual selves or more language-specific integrative ideal selves. The other profile was dominated by an instrumental orientation and generated diminishing motivational forces.

Another branch probes into how these learner-internal factors impact learners' divergent language achievements (e.g. Kliesch & Pfenninger, 2021; Li, Dewaele, & Jiang, 2019; Lowie & Verspoor, 2019; Nematizadeh & Wood, 2019; Wood, 2016), grounded in the assumption that even a minor distinction in the initial conditions or in the interplay of internal and external components during the course of their learning could exert a huge impact on their diverse outcomes (Larsen-Freeman & Cameron 2008). For example, Kliesch and Pfenninger (2021) traced 28 older (age 65+) German-speaking learners of Spanish over 7 months. They found a significant moderating effect of education, age, and multilingualism on the L2 proficiency level and the developmental patterns over time, but hardly any relationship between the development of cognition and socioaffect and of L2 performance. Li, Dewaele and Jiang (2019) examined 1,307 Chinese students' anxiety and enjoyment, their interaction, their effects on learners' English achievements, and the effect of English achievements on them. They found negative interaction between the two emotions in three groups of learners with different English achievements. Anxiety was negatively associated with proficiency while enjoyment was positively associated with proficiency in nearly all groups except for one low achievement group. They suggested that learners at lower proficiency levels were more likely to experience heightened anxiety and reduced enjoyment in the language learning process.

L2 Teacher and Teaching

The theme of L2 teacher and teaching is more related to the context in which language teaching is situated. This review has shown that the prevalent studies have been conducted in the classroom-based instructional context. CDST acknowledges that language learning and teaching are not isolated, static, or linear processes but are instead situated within, emerging from, and dynamically connected to the temporal and spatial environment (Larsen-Freeman, 2018). This perspective shift has ignited research interest in the practice, perception, and challenges of language teacher and teaching.

A salient trend in CDST research over the years has been ascribed to the co-adaptive practice in language teaching (e.g. Fogal & Koyama, 2022; Feryok & Oranje, 2015; Kostoulas, Stelma, Mercer, Cameron, & Dawson, 2018; Rahman & Singh, 2021; Smith & King, 2017; Sun & Zhang, 2022). While the traditional research on teaching "assumes that causation in classrooms operates unilaterally from the teacher to the students" (Bolster, 1983, p.302), a CDST view of teaching attempts to explore the reciprocal effects between students and teachers. For example, Fogal and Koyama (2022) investigated the contextual affordances and

the co-adaptive processes through journaling and journaling feedback in a classroom-based educational practice. Smith and King (2017) observed a postgraduate L2 classroom and examined the effect of teacher's elicitation types and wait time on student discourse. They found wait-time interactions could lead to non-linear and feedback-sensitive reactions in the classroom discourse system.

Another line of CDST research pays attention to language teachers' perceptions, as well as teachers' motivation, beliefs, awareness, self-efficacy, identity, and agency (e.g. Aslan, 2015; Sak, 2022; Sampson, 2016; Sahin & Yildirim, 2016; Yu, Xu, Jiang, & Chan, 2020; Zheng, 2013). The importance of context not only lies in its presence and influence on language teaching and learning, but also in how they are perceived by agents as offering the basis for action (Larsen-Freeman, 2016; van Lier, 2004). As such, teachers' perceptions might have a huge impact on their teaching practice as teachers are confronted with diverse situations. For example, Aslan (2015) investigated the cognition, identity, and practice of a teacher with dual language identity – both a French native speaker and a German non-native speaker. Their research revealed that the identity as a dual language teacher as well as the early language learning experiences influenced the teachers' beliefs about teaching contents and processes.

Language teacher and teaching are confronted with manifold challenges (e.g. Qi & Wang, 2022; Ratih, Kurniawan, Nurhidayat, Prayitno, & Buan, 2021; Sulis, Mercer, Mairitsch, Babic, & Shin, 2021), such as the trend of globalization and the advancement of technology, which are considered as parameters that disturb teachers' attractor state and pull the teachers into the compeller state, where they self-organize and make adjustments to the new environment (Larsen-Freeman & Cameron, 2008). For instance, Ratih, Kurniawan, Nurhidayat, Prayitno and Buan (2021) investigated the challenges and adjustments confronting pre-service English teachers when taking an international internship. Their findings revealed that these teachers encountered a range of challenges throughout the stages of pre-, while-, and post-teaching when adapting to a new educational system. Qi and Wang (2022) examined the challenges faced by a Chinese-as-a-Second-Language teacher in a blended classroom, composed of both an offline cohort and an online cohort of students simultaneously. They found the teachers' agency and action changed in complex and dynamic ways when encountering the new teaching context and technology.

Conclusion and Future Directions

So far, we have reviewed and discussed L2 empirical research framed within CDST from 2008 to 2022. A total of 198 studies have been reviewed and three research themes have emerged. Our findings revealed that the inception of CDST-inspired L2 research lies in the investigation of the language systems, unraveling the dynamic developmental trajectories, and seeking emergent group patterns. A second line of research probes into the internal factors of language learners, in an attempt to unpack their interconnected and dynamic structures and development, as well as their impacts on diverse language achievements. Attention has also been paid to the practice, perception, and challenges of language teacher and teaching. All of the three themes are indispensable constituents of L2 research under CDST, as they are reciprocally constructed in a complex and dynamic fashion at the micro, meso, and macro levels (Figure 4).

Against a mainstream model of language learning and teaching (The Douglas Fir Group, 2016), this review has found that the current CDST research is mostly confined to the micro-

level examination of the language systems and agent-internal factors under meso-level social engagement contexts. However, the investigation into the macro-level ideology and practice is still in dearth. Therefore, over and above a synthesis of the current research, we suggest three trends that might inspire future efforts.

Figure 4

Current State of L2 Research Framed within CDST (Adapted from The Douglas Fir Group [2016])
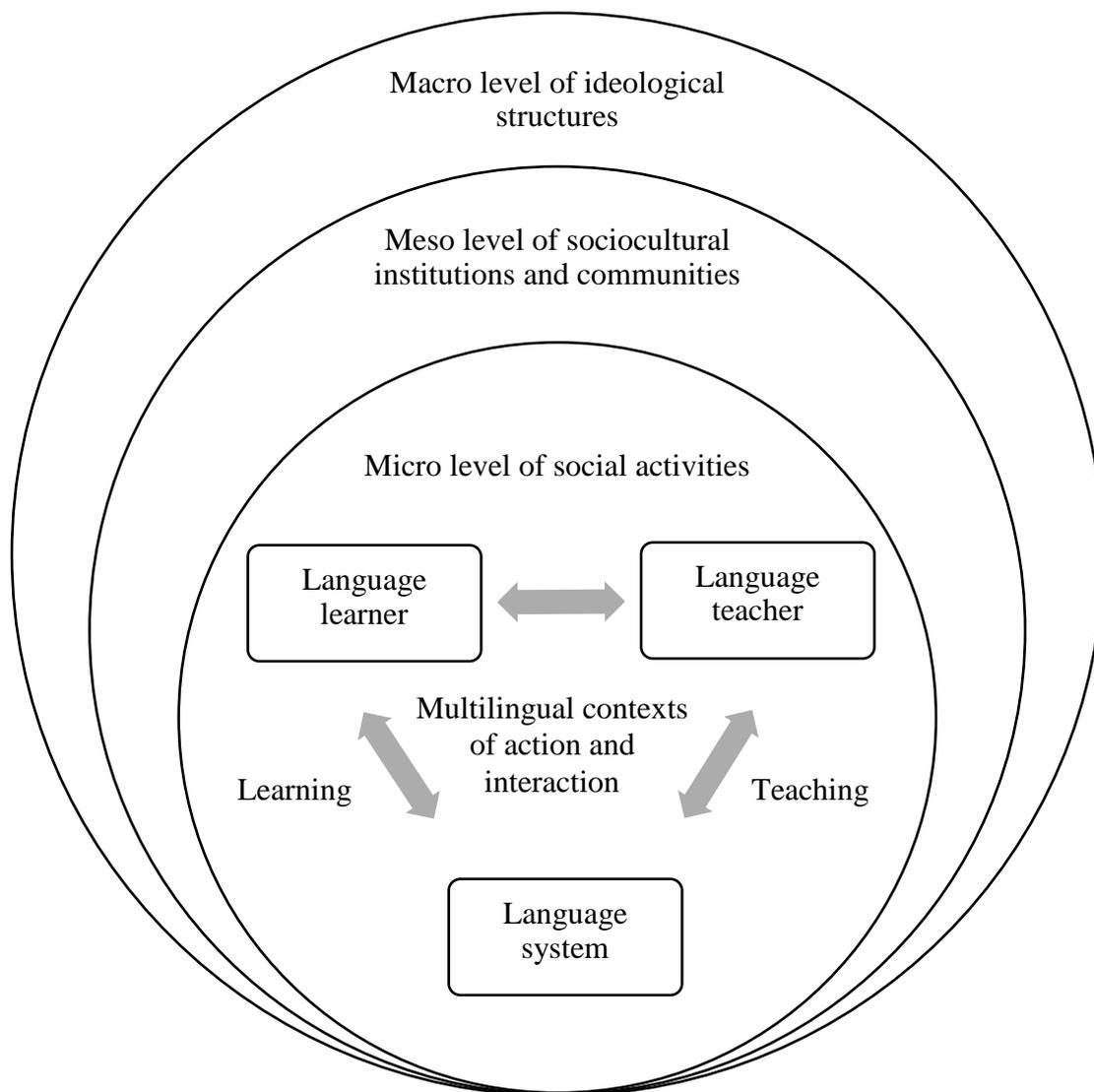
At the micro level, complex as the language system is, the present review has found that the prevalent CDST research has predominantly concentrated on the lexical and syntactic subsystems, with only a small number of studies on other subsystems (e.g. de Leeuw, Mennen, and Scobbie's [2013] exploration on the phonetic subsystem). A future attempt is to explore how different subsystems of language (e.g. morphology, phonetics, semantics, pragmatics) would interact and develop at different rates and scales. In addition, our findings have showed that while much of the current attention has been paid to the second language, relatively little has been paid to other languages, with only a few exceptions (e.g. Opitz's [2013] exploration on L1 attrition, Huang, Steinkrauss and Verspoor's [2022] investigation on L3 influence). The examination of the bidirectional positive and negative influence among multiple language systems would also be inspiring for future research. On the other hand, despite a branch of the latest CDST studies exploring the group trends in language development, evidence still comes short to confirm CDST claims beyond the individual cases (Bulté & Housen, 2020). The inclusion of more group-level research would be valuable in establishing a robust foundation for supporting CDST claims.

At the meso level, a majority of reviewed CDST studies have been based on the traditional classroom context. On the one side, this has left a large picture of other contexts where language use takes place untouched, e.g. family, neighborhood, workplace, worship place, and social organizations (The Douglas Fir Group, 2016). On the other side, the rapid advancement in technology is poised to reshape our world, compressing time and space (Larsen-Freeman, 2018), and even creating entirely new time and space. Future research would move beyond treating technology only as assisting tools for language learning and teaching, and would instead focus on the new technology-created time and space. This could involve investigating how emerging platforms like online meeting rooms, metaverse environments, and chatbots construct new cyberspaces as settings for language learning and teaching. While this endeavor has already begun in language learning and teaching research beyond the scope of CDST, it is important to note that CDST research has made limited inroads into this area. CDST holds the potential to explore how these technologies offer affordances to learners and teachers, reshaping the way they interact and co-adapt in these evolving digital environments.

At the macro level, CDST embraces a multilingual world, recognizing and valuing the coexistence of multiple languages, varieties, dialects, and their accompanying identities (Larsen-Freeman, 2018). However, despite the much theoretical advancement made by CDST, empirical research concerning the practical implementation of the macro-level CDST ideology of language, language learning and teaching remains largely underexplored. For instance, future efforts could be put into designing language assessments that acknowledge learners' developing capacity rather than their static competence (Larsen-Freeman, 2015), avoiding the "one-size-fits-all" approach to set the same learning goal in the same classroom composed of learners from various linguistic backgrounds (Larsen-Freeman & Tedick, 2016, p. 1339), and even more macro-level language management and planning.

Finally, this review also validates the feasibility and effectiveness of textometry as a computer-supported qualitative method for conducting literature review. Textometric tools like IRAMUTEQ bear the merit of detecting themes from the big data in a bottom-up way. They bring to light new perspectives, interpretations, and relationships that might otherwise remain

hidden in manual coding (Ramos, do Rosário Lima, & Amaral-Rosa, 2019). Furthermore, they are more efficient and objective as compared with human judgment.

ORCID

https://orcid.org/0000-0001-8411-5646

https://orcid.org/0000-0002-0664-3942

Ethics Declarations

Competing Interests

No, there are no conflicting interests.

Rights and Permissions

Open Access

References

Aslan, E. (2015). When the native is also a non-native: "Retrodicting" the complexity of language teacher cognition. *The Canadian Modern Language Review, 71*, 244-269. https://doi.org/10.3138/cmlr.2575

Baba, K. & Nitta, R. (2014). Phase transitions in development of writing fluency from a complex dynamic systems perspective. *Language Learning, 64*(1), 1-35. https://doi.org/10.1111/lang.12033

Baba, K. & Nitta, R. (2021). Emergence of multiple groups of learners with different writing-development trajectories in classroom: Growth mixture modeling. *Journal of Second Language Writing, 54*, 100856. https://doi.org/10.1016/j.jslw.2021.100856

Bart, D. (2011). L'analyse de données textuelles avec le logiciel ALCESTE. *Recherches en Didactiques, 12* (2), 173–184. https://doi.org/10.3917/rdid.012.0173

Bolster, A. S. (1983). Toward a more effective model of research on teaching. *Harvard Educational Review, 53*(3), 294-308. https://doi.org/10.17763/haer.53.3.0105420v41776340

Bulté, B. & Housen, A. (2020). A critical appraisal of the CDST approach to investigating linguistic complexity in L2 writing development. In G. Fogal & M. Verspoor (Eds.). *Complex dynamic systems theory and L2 writing development* (pp. 207-238). John Benjamins. https://doi.org/10.1075/lllt.54.09bul

Camargo, B. V. & Justo, A. M. (2013). IRAMUTEQ: Um software gratuito para análise de dados textuais (IRAMUTEQ: A free software for textual data analysis). *Temas em Psicologia, 21* (2), 513–518. http://dx.doi.org/10.9788/TP2013.2-16

de Bot, K. & Larsen-Freeman, D. (2011). Researching second language development from a dynamic systems theory perspective. In M. Verspoor, K. de Bot & W. Lowie (Eds.), *A dynamic approach to second language development: Methods and techniques* (pp. 5–24). Benjamins. https://doi.org/10.1075/lllt.29.01deb

de Leeuw, E., Mennen, I. & Scobbie, J. M. (2013). Dynamic systems, maturational constraints and L1 phonetic attrition. *International Journal of Bilingualism, 17,* 683-700. https://doi.org/10.1177/1367006912454620

Dewaele, J. & Pavelescu, L. M. (2019). The relationship between incommensurable emotions and willingness to communicate in English as a foreign language: A multiple case study. *Innovation in Language Learning and Teaching, 15*, 66-80. https://doi.org/10.1080/17501229.2019.1675667

Ellis, N. C. & Larsen-Freeman, D. (2006). Language emergence: Implications for applied linguistics - Introduction to the special issue. *Applied Linguistics, 27*, 558-589. https://doi.org/10.1093/applin/aml028

Feldman R. & Sanger J. (2006). *The text mining handbook: Advanced approaches in analyzing unstructured data.* Cambridge University Press. https://doi.org/10.1017/CBO9780511546914

Feryok, A. & Oranje, J. (2015). Adopting a cultural portfolio project in teaching German as a foreign language: Language teacher cognition as a dynamic system. *The Modern Language Journal, 99*, 546-564. https://doi.org/10.1111/modl.12243

Fogal, G. G. & Koyama, D. (2022). A study of co-adaptation through journaling. *Journal of Second Language Writing. 55,* 100873. https://doi.org/10.1016/j.jslw.2022.100873

Fogal, G. G. (2022). Second language writing from a complex dynamic systems perspective. *Language Teaching, 55*, 193-210. https://doi.org/10.1017/S0261444821000410

Fonseca, A., Abreu, I., Guerreiro, M. J. & Barros, N. (2022). Indoor air quality in healthcare units - A systematic literature review focusing recent research. *Sustainability, 14*(2), 967. https://doi.org/10.3390/su14020967

Gui, M., Chen, X. & Verspoor, M. H. (2021). The dynamics of reading development in L2 English for academic purposes. *System, 100,* 102546. https://doi.org/10.1016/j.system.2021.102546

Han, J. & Hiver, P. (2018). Genre-based L2 writing instruction and writing-specific psychological factors: The dynamics of change. *Journal of Second Language Writing, 40*, 44-59. https://doi.org/10.1016/j.jslw.2018.03.001

Han, Z., Kang, E. & Sok, S. (2023). The complexity epistemology and ontology in second language acquisition: A critical review. *Studies in Second Language Acquisition, 45*(5), 1388-1412. https://doi.org/10.1017/S0272263122000420

Hiver, P. & Al-Hoorie, A. H. (2020). *Research methods for complexity theory in applied linguistics.* Multilingual Matters. https://doi.org/10.21832/HIVER5747

Hiver, P., Al-Hoorie, A. & Evans, R. (2022). Complex dynamic systems theory in language learning: A scoping review of 25 years of research. *Studies in Second Language Acquisition, 44*(4), 913-941. https://doi.org/10.1017/S0272263121000553

Huang, T., Steinkrauss, R. & Verspoor, M. (2021). Variability as predictor in L2 writing proficiency. *Journal of Second Language Writing 52*(4), 100787. https://doi.org/10.1016/j.jslw.2020.100787

Huang, T., Steinkrauss, R. & Verspoor, M. H. (2022). Learning an L2 and L3 at the same time: Help or hinder? *International Journal of Multilingualism, 19*, 566-582. https://doi.org/10.1080/14790718.2020.1779726

In'nami, Y. & Koizumi, R. (2010). Database selection guidelines for meta-analysis in applied linguistics. *TESOL Quarterly*, *44*(1), 169–184. https://doi.org/10.5054/tq.2010.215253

Kiss, T. & Pack, A. (2022). A network analysis of L2 motivational factors: Structure, connectivity, and central relational links. *TESOL Quarterly, 57*(2), 537-565. https://doi.org/10.1002/tesq.3166

Kliesch, M. and Pfenninger, S. E. (2021). Cognitive and socioaffective predictors of l2 microdevelopment in late adulthood: A longitudinal intervention study. *The Modern Language Journal, 105*, 237-266. https://doi.org/10.1111/modl.12696

Kostoulas, A., Stelma, J., Mercer, S., Cameron, L. & Dawson, S. (2018). Complex systems theory as a shared discourse space for TESOL. *TESOL Journal, 9*, 246-260. https://doi.org/10.1002/tesj.317

Larsen-Freeman, D. (1997). Chaos/complexity science and second language acquisition. *Applied Linguistics, 18*(2), 141-65. https://doi.org/10.1093/applin/18.2.141

Larsen-Freeman, D. (2006a). Second language acquisition and fossilization: There is no end, and there is no state. In Z. H. Han & T. Odlin (Eds.), *Studies of fossilization in second language acquisition* (pp. 189–200). Multilingual Matters. https://doi.org/10.21832/9781853598371-012

Larsen-Freeman, D. (2006b). The emergence of complexity, fluency, and accuracy in the oral and written production of five Chinese learners of English. *Applied Linguistics, 27*, 590–619. https://doi.org/10.1093/applin/aml029

Larsen-Freeman, D. & Cameron, L. (2008). *Complex systems and applied linguistics.* Oxford University Press. https://doi.org/10.1111/j.1473-4192.2007.00148.x

Larsen-Freeman, D. (2012). The emancipation of the language learner. *Studies in Second Language Learning and Teaching, 2*, 297-309. https://doi.org/10.14746/ssllt.2012.2.3.2

Larsen-Freeman, D. (2015). Saying what we mean: Making a case for 'language acquisition' to become 'language development'. *Language Teaching, 48*, 491-505. https://doi.org/10.1017/S0261444814000019

Larsen-Freeman, D. (2016). Classroom-oriented research from a complex systems perspective. *Studies in Second Language Learning and Teaching, 6*, 377-393. https://doi.org/10.14746/ssllt.2016.6.3.2

Larsen-Freeman, D. & Tedick, D. J. (2016). Teaching world languages: Thinking differently. In D. H. Gitomer & C. A. Bell (Eds.), *Handbook of research on teaching* (pp. 1335-1388). American Educational Research Association. https://doi.org/10.3102/978-0-935302-48-6_22

Larsen-Freeman, D. (2018). Looking ahead: Future directions in, and future research into, second language acquisition. *Foreign Language Annals, 51*, 55-72. https://doi.org/10.1111/flan.12314

Larsen–Freeman, D. (2019). On language learner agency: A complex dynamic systems theory perspective. The *Modern Language Journal, 103*, 61-79. https://doi.org/10.1111/modl.12536

Lavissière, A., Sohier, R. & Lavissière, M. C. (2020). Transportation systems in the Arctic: A systematic literature review using textometry. *Transportation Research Part A-policy and Practice, 141*, 130-146. https://doi.org/10.1016/j.tra.2020.09.003

Li, C., Dewaele, J. & Jiang, G. (2019). The complex relationship between classroom emotions and EFL achievement in China. *Applied Linguistics Review, 11*, 485-510. https://doi.org/10.1515/applirev-2018-0043

Lowie, W. & Verspoor, M. H. (2015). Variability and variation in second language acquisition orders: A dynamic reevaluation. *Language Learning, 65*, 63-88. https://doi.org/10.1111/lang.12093

Lowie, W. & Verspoor, M. H. (2019). Individual differences and the ergodicity problem. *Language Learning, 69*(s1), 184-206. https://doi.org/10.1111/lang.12324

MacIntyre, P. D. & Legatto, J. J. (2011). A dynamic system approach to willingness to communicate: Developing an idiodynamic method to capture rapidly changing affect. *Applied Linguistics, 32,* 149-171. https://doi.org/10.1093/applin/amq037

MacIntyre, P. D. & Wang, L. (2021). Willingness to communicate in the L2 about meaningful photos: Application of the pyramid model of WTC. *Language Teaching Research, 25*, 878-898. https://doi.org/10.1177/13621688211004645

Molenaar, P. C. (2015). On the relation between person-oriented and subject-specific approaches. *Journal for Person-Oriented Research, 1*, 34–41. https://doi.org/10.17505/jpor.2015.04

Nematizadeh, S. & Wood, D. R. (2019). Willingness to communicate and second language speech fluency: An investigation of affective and cognitive dynamics. *The Canadian Modern Language Review, 75*(3), 197-215. https://doi.org/10.3138/cmlr.2017-0146

Opitz, C. (2013). A dynamic perspective on late bilinguals' linguistic development in an L2 environment. *International Journal of Bilingualism, 17*, 701-715. https://doi.org/10.1177/1367006912454621

Ortega, L. (2017, October 14). *The bi/multilingual turn in SLA: How far have we (not) come, and why?* [Conference presentation] Plenary address, Second Language Research Forum 2017 conference, Ohio State University, Columbus.

Oswald, F. L. & Plonsky, L. (2010). Meta-analysis in second language research: Choices and challenges. *Annual Review of Applied Linguistics, 30*, 85–110. https://doi.org/10.1017/S0267190510000115

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., *et al.* (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The British Medical Journal*, *372*(n71). https://doi.org/10.1136/bmj.n71

Peng, H., W. Lowie & Jager, S. (2022). Unravelling the idiosyncrasy and commonality in L2 developmental processes: A time-series clustering methodology. *Applied Linguistic 43*(5), 891-911. https://doi.org/10.1093/applin/amac011

Pincemin, B. & Heiden, S. (2008). What is textometry? *Textometry project website.* https://txm.gitpages.huma-num.fr/textometrie/en/Introduction/ (accessed December 3 2023)

Pincemin, B. & Marchand, S. (2022). An experiment on Plato's gorgias as an introduction to textometry. *Classics@ 20.* https://classics-at.chs.harvard.edu/an-experiment-on-platos-gorgias-as-an-introduction-to-textometry/ (accessed December 3 2023)

Plonsky, L. & Brown, D. (2015). Domain definition and search techniques in meta-analyses of L2 research (or why 18 meta-analyses of feedback have different results). *Second Language Research, 31*, 267–276. https://doi.org/10.1177/0267658314536436

Polat, B. & Kim, Y. J. (2014). Dynamics of complexity and accuracy: A longitudinal case study of advanced untutored development. *Applied Linguistics, 35*, 184-207. https://doi.org/10.1093/applin/amt013

Qi, G. Y. & Wang, Y. (2022). Challenges and responses: A complex dynamic systems approach to exploring language teacher agency in a blended classroom. *The JALT CALL Journal, 18*(1), 54–82. https://doi.org/10.29140/jaltcall.v18n1.569

Rahman, M. M. & Singh, M. K. (2021). Complex dynamic systems of language teacher cognitions: A case study from Bangladesh. *Issues in Educational Research, 31*(1), 241-245. http://www.iier.org.au/iier31/rahman.pdf

Ramos, M. G., do Rosário Lima, V. M., & Amaral-Rosa, M. P. (2019). IRAMUTEQ software and discursive textual analysis: Interpretive possibilities. In A. Costa, L. Reis, A. Moreira (Eds.). *Computer supported qualitative research* (pp. 58–72). https://doi.org/10.1007/978-3-030-01406-3_6

Ratih, K., Kurniawan, F. A., Nurhidayat, N., Prayitno, H. J. & Buan, A. T. (2021). Challenges and adjustments in undertaking teaching practice across countries in disruptive era of education. *Asian Journal of University Education, 17*(4), 339-407. https://doi.org/10.24191/ajue.v17i4.16206

Reinert, M. (1983). Une méthode de classification descendante hiérarchique: Application à l'analyse lexicale par context. *Les Cahiers de L'analyse des Données, 8*, 187-198.

Reinert, M. (1990). ALCESTE, une méthodologie d'analyse des données textuelles et une application: Aurélia de G. de Nerval. *Bulletin de Méthodologie Sociologique, 26*, 24-54. https://doi.org/10.1177/075910639002600103

Reinert, M., (1993). Les "mondes lexicaux" et leur "logique" à travers l'analyse statistique d'un corpus de récits de cauchemars. *Langage et Société 66*(1), 5–39. https://doi.org/10.3406/LSOC.1993.2632

Sahin, I. & Yildırım, A. (2016). Transforming professional learning into practice. *ELT Journal, 70*, 241-252. https://doi.org/10.1093/elt/ccv070

Sak, M. (2022). Dynamicity of language teacher motivation in online EFL classes. *System, 111,* 102948. https://doi.org/10.1016/j.system.2022.102948

Sampson, R. J. (2016). EFL teacher motivation in-situ: Co-adaptive processes, openness and relational motivation over interacting timescales. *Studies in Second Language Learning and Teaching, 6*, 293-318. https://doi.org/10.14746/ssllt.2016.6.2.6

Smith, L., & King, J. (2017). A dynamic systems approach to wait time in the second language classroom. *System, 68,* 1-14. https://doi.org/10.1016/J.SYSTEM.2017.05.005

Spoelman, M. & Verspoor, M. (2010). Dynamic patterns in development of accuracy and complexity: A longitudinal case study in the acquisition of Finnish. *Applied Linguistics, 31*(4), 532-553. https://doi.org/0.1093/applin/amq001

Sulis, G., Mercer, S., Mairitsch, A., Babic, S. & Shin, S. (2021). Pre-service language teacher wellbeing as a complex dynamic system. *System, 103*, 102642. https://doi.org/10.1016/j.system.2021.102642

Sun, Q. & Zhang, L. J. (2022). Understanding novice and experienced teachers' cognitions and practices for sustainable teacher development: The case of form-focused instruction in English language teaching. *Sustainability, 14*, 4711. https://doi.org/10.3390/su14084711

The Douglas Fir Group. (2016). A transdisciplinary framework for SLA in a multilingual world. *The Modern Language Journal, 100,* 19-47. https://doi.org/10.1111/modl.12301

Thelen, E. & Smith, L. (1994). *A dynamic systems approach to the development of cognition and action*. The MIT Press. https://doi.org/10.7551/mitpress/2524.001.0001

van Lier, L. (2004). *The ecology and semiotics of language learning: A sociocultural perspective*. Kluwer.

Verspoor, M., Lowie, W. & van Dijk, M. (2008). Variability in second language development from a dynamic systems perspective. *The Modern Language Journal, 92*(2), 214-231. https://doi.org/10.1111/j.1540-4781.2008.00715.x

Verspoor, M. & de Bot, K. (2021). Measures of variability in transitional phases in second language development. *International Review of Applied Linguistics in Language Teaching, 60*(1), 85-101. https://doi.org/10.1515/iral-2021-0026

Verspoor, M., Lowie, W. & de Bot, K. (2021). Variability as normal as apple pie. *Linguistics Vanguard, 7*(s2), 20200034. https://doi.org/10.1515/lingvan-2020-0034

Wood, D. R. (2016). Willingness to communicate and second language speech fluency: An idiodynamic investigation. *System, 60,* 11-28. https://doi.org/10.1016/j.system.2016.05.003

Yu, H. & Lowie, W. (2020). Dynamic paths of complexity and accuracy in second language speech: A longitudinal case study of Chinese learners. *Applied Linguistics, 41*(6), 855-877. https://doi.org/10.1093/applin/amz040

Yu, H., Lowie, W. & Peng, H. (2022). Understanding salient trajectories and emerging profiles in the development of Chinese learners' motivation: A growth mixture modeling approach. *International Review of Applied Linguistics in Language Teaching*. https://doi.org/10.1515/iral-2022-0036

Yu, S., Xu, H., Jiang, L. & Chan, I. K. (2020). Understanding Macau novice secondary teachers' beliefs and practices of EFL writing instruction: A complexity theory perspective. *Journal of Second Language Writing, 48*, 100728. https://doi.org/10.1016/j.jslw.2020.100728

Zhang, S., Zhang, H. & Zhang, C. (2022). A dynamic systems study on complexity, accuracy, and fluency in english writing development by Chinese university students. *Frontiers in Psychology, 13,* 787710. https://doi.org/10.3389/fpsyg.2022.787710

Zheng, H. (2013). The dynamic interactive relationship between Chinese secondary school EFL teachers' beliefs and practice. *The Language Learning Journal, 41,* 192-204. https://doi.org/10.1080/09571736.2013.790133

Zheng, Y. (2016). The complex, dynamic development of L2 lexical use: A longitudinal study on Chinese learners of English. *System, 56*, 40-53. https://doi.org/10.1016/j.system.2015.11.007

Zheng, Y., Lu, X. & Ren, W. (2020). Tracking the evolution of Chinese learners' multilingual motivation through a longitudinal q methodology. *The Modern Language Journal, 104*, 781-803. https://doi.org/10.1111/modl.12672

Supplementary Materials

Ahmed, S. (2017). Exploring the variability of the preposition "in" in written communication. *Studies in Applied Linguistics & TESOL, 17*(1), 24-38. https://doi.org/10.7916/salt.v17i1.1236

Amerstorfer, C. M. (2020). The dynamism of strategic learning: Complexity theory in strategic L2 development. *Studies in Second Language Learning and Teaching, 10,* 21-44. http://dx.doi.org/10.14746/ssllt.2020.10.1.2

Aslan, E. (2015). When the native is also a non-native: "retrodicting" the complexity of language teacher cognition. *The Canadian Modern Language Review, 71*, 244-269. https://doi.org/10.3138/cmlr.2575

Baba, K. & Nitta, R. (2014). Phase transitions in development of writing fluency from a complex dynamic systems perspective. *Language Learning, 64*(1), 1-35. https://doi.org/10.1111/lang.12033

Baba, K. & Nitta, R. (2021). Emergence of multiple groups of learners with different writing-development trajectories in classroom: Growth mixture modeling. *Journal of Second Language Writing.* https://doi.org/10.1016/j.jslw.2021.100856

Bahari, A. (2019). FonF practice model from theory to practice: CALL via focus on form approach and non-linear dynamic motivation to develop listening and speaking proficiency. *Computer & Education, 130,* 40-58. https://doi.org/10.1016/j.compedu.2018.11.009

Bahari, A. (2022). Game-based collaborative vocabulary learning in blended and distance L2 learning. *Open Learning: The Journal of Open, Distance and e-Learning, 37,* 348-369. https://doi.org/10.1080/02680513.2020.1814229

Barrett, N. E., Liu, G. & Wang, H. (2022). Student perceptions of a mobile learning application for english oral presentations: The case of EOPA. *Computer Assisted Language Learning, 35,* 2476-2501. https://doi.org/10.1080/09588221.2021.1881975

Baten, K. & Håkansson, G. (2015). The development of subordinate clauses in German and Swedish as L2s: A theoretical and methodological comparison. *Studies in Second Language Acquisition, 37*(2), 517–547. https://doi.org/10.1017/S0272263114000552

Blank, C. A. & Zimmer, M. C. (2011). The influence of orthography on a lexical access task involving L2 (French) and L3 (English) of a multilingual individual: A dynamic systems approach. *Calidoscópio, 9*(1), 28-40. https://doi.org/10.4013/cld.2011.91.03

Booth, P. A. (2014). The variance of lexical diversity profiles and its relationship to learning style. *International Review of Applied Linguistics in Language Teaching, 52,* 357-375. https://doi.org/10.1515/iral-2014-0015

Bower, K. (2019). Explaining motivation in language learning: A framework for evaluation and research. *The Language Learning Journal, 47,* 558-574. https://doi.org/10.1080/09571736.2017.1321035

Bui, G. & Teng, F. (2021). Exploring complexity in L2 and L3 motivational systems: A dynamic systems theory perspective. *The Language Learning Journal, 49,* 302-317. https://doi.org/10.1080/09571736.2019.1610032

Burgh-Hirabe, R. D. & Feryok, A. (2013). A model of motivation for extensive reading in Japanese as a foreign language. *Reading in a Foreign Language, 25*, 72-93. http://hdl.handle.net/10125/66678

Castro, E. (2018). Complex adaptive systems, language advising, and motivation: A longitudinal case study with a Brazilian student of English. *System, 74*, 138-148. https://doi.org/10.1016/j.system.2018.03.004

Castro, E. (2019). Motivational dynamics in language advising sessions: A case study. *Studies in Self-Access Learning Journal, 10*(1), 5-20. https://doi.org/10.37237/100102

Chan, H., Verspoor, M. H. & Vahtrick, L. (2015). Dynamic development in speaking versus writing in identical twins. *Language Learning, 65,* 298-325. https://doi.org/10.1111/lang.12107

Chang, C. B. (2013). A novelty effect in phonetic drift of the native language. *Journal of Phonetics, 41*, 520-533. https://doi.org/10.1016/j.wocn.2013.09.006

Chang, P. & Zhang, L. J. (2021). A CDST perspective on variability in foreign language learners' listening development. *Frontiers in Psychology, 12*, 601962. https://doi.org/10.3389/fpsyg.2021.601962

Cherciov, M. (2013). Investigating the impact of attitude on first language attrition and second language acquisition from a dynamic systems theory perspective. *International Journal of Bilingualism, 17*, 716-733. https://doi.org/10.1177/1367006912454622

Choe, A. T. (2017). Exploring the dynamics of willingness to communicate in written communication: A case study. *Studies in Applied Linguistics & TESOL, 17*(1), 39-55. https://doi.org/10.7916/salt.v17i1.1237

Churchill, E. (2008). A dynamic systems account of learning a word: From ecology to form relations. *Applied Linguistics, 29*(3), 339-358. https://doi.org/10.1093/applin/amm019

Csizér, K. & Lukacs, G. (2010). The comparative analysis of motivation, attitudes and selves: The case of English and German in Hungary. *System, 38*, 1-13. https://doi.org/10.1016/J.SYSTEM.2009.12.001

Cui, T. & Yang, Y. (2022). Social relationships and grit in English as a foreign language learning among high school students: A three-wave longitudinal study. *Frontiers in Psychology, 13*, 1038878. https://doi.org/10.3389/fpsyg.2022.1038878

de Bot, K., Chan, B., Lowie, W., Plat, R. & Verspoor, M. H. (2012). A dynamic perspective on language processing and development. *Dutch Journal of Applied Linguistics, 1*(2), 188-218. https://doi.org/10.1075/dujal.1.2.03deb

de Leeuw, E., Mennen, I. & Scobbie, J. M. (2013). Dynamic systems, maturational constraints and L1 phonetic attrition. *International Journal of Bilingualism, 17,* 683-700. https://doi.org/10.1177/1367006912454620

de Oliveira e Paiva, V. L. M. & de Carvalho Fidelis Braga, J. (2008). The complex nature of autonomy. *DELTA: Documentação de Estudos em Lingüística Teórica e Aplicada, 24*, 441-468. https://doi.org/10.1590/S0102-44502008000300004

de Ruiter, N. M., Elahi Shirvan, M. & Talebzadeh, N. (2019). Emotional processes of foreign-language learning situated in real-time teacher support. *Ecological Psychology, 31*, 127-145. https://doi.org/10.1080/10407413.2018.1554368

Dean, A. C. (2017). Complex dynamic systems and interlanguage variability: Investigating topic, syntactic complexity, and accuracy in NS-NNS written interaction. *Studies in Applied Linguistics & TESOL, 17*(1), 56-97. https://doi.org/10.7916/salt.v17i1.1238

Dewaele, J. & Pavelescu, L.M. (2021). The relationship between incommensurable emotions and willingness to communicate in English as a foreign language: A multiple case study. *Innovation in Language Learning and Teaching, 15*, 66-80. https://doi.org/10.1080/17501229.2019.1675667

Dong, J. (2016). A dynamic systems theory approach to development of listening strategy use and listening performance. *System, 63*, 149-165. https://doi.org/10.1016/j.system.2016.10.004

Dong, J., Buckingham, L. & Wu, H. (2021). A discourse dynamics exploration of attitudinal responses towards COVID-19 in academia and media. *International Journal of Corpus Linguistics, 26*(4), 532-556. https://doi.org/10.1075/ijcl.21103.don

Dong, Y. & Liu, S. (2020). Dynamic features of students' scaffolding interaction in English writing class. *Theory and Practice in Language Studies, 10*, 647-656. http://dx.doi.org/10.17507/tpls.1006.04

Dong, Y. (2018). Complex dynamic systems in students of interpreting training. *Translation and Interpreting Studies, 13*(2), 185-207. https://doi.org/10.1075/tis.00011.don

Du, J. (2022). In search of well-established evaluative criteria for the emerging qualitative methods of L2 affective variables. *Frontiers in Psychology, 13*, 995761. https://doi.org/10.3389/fpsyg.2022.995761

Duan, S. & Shi, Z. (2021). A longitudinal study of formulaic sequence use in second language writing: Complex dynamic systems perspective. *Language Teaching Research.* https://doi.org/10.1177/13621688211002942

Ducker, N. T. (2022). A situated examination of the complex dynamic nature of L2 listening in EMI. *Language Teaching Research.* https://doi.org/10.1177/13621688221124439

Ebert, K. D., Pham, G. T. & Kohnert, K. J. (2014). Lexical profiles of bilingual children with primary language impairment. *Bilingualism: Language and Cognition, 17*, 766-783. https://doi.org/10.1017/S1366728913000825

Eddy-U, M. E. (2015). Motivation for participation or non-participation in group tasks: A dynamic systems model of task-situated willingness to communicate. *System, 50*, 43-55. https://doi.org/10.1016/j.system.2015.03.005

Elahi Shirvan, M. & Talebzadeh, N. (2017). English as a foreign language learners' anxiety and interlocutors' status and familiarity: An idiodynamic perspective. *Polish Psychological Bulletin, 48*, 489-503. https://doi.org/10.1515/ppb-2017-0056

Elahi Shirvan, M. & Talebzadeh, N. (2018). Exploring the fluctuations of foreign language enjoyment in conversation: An idiodynamic perspective. *Journal of Intercultural Communication Research, 47*, 21-37. https://doi.org/10.1080/17475759.2017.1400458

Elahi Shirvan, M., Taherian, T. & Yazdanmehr, E. (2020). The dynamics of foreign language enjoyment: An ecological momentary assessment. *Frontiers in Psychology, 11*, 1391. https://doi.org/10.3389/fpsyg.2020.01391

Elahi Shirvan, M., Taherian, T. & Yazdanmehr, E. (2021). Foreign language enjoyment: A longitudinal confirmatory factor analysis–curve of factors model. *Journal of Multilingual and Multicultural Development.* https://doi.org/10.1080/01434632.2021.1874392

Elahi Shirvan, M., Taherian, T., Shahnama, M. & Yazdanmehr, E. (2021). A longitudinal study of foreign language enjoyment and l2 grit: A latent growth curve modeling. *Frontiers in Psychology, 12,* 720326. https://doi.org/10.3389/fpsyg.2021.720326

Evans, D. R. (2020). On the fractal nature of complex syntax and the timescale problem. *Studies in Second Language Learning and Teaching, 10*(4), 697-721. http://dx.doi.org/10.14746/ssllt.2020.10.4.3

Evans, D. R., & Larsen-Freeman, D. (2020). Bifurcations and the emergence of l2 syntactic structures in a complex dynamic system. *Frontiers in Psychology, 11*, 574603. https://doi.org/10.3389/fpsyg.2020.574603

Fadilah, E., Widiati, U. & Latief, M.A. (2019). Reading dynamic patterns of silence as a communication strategy and impediment in the EFL classroom interaction. *International Journal of Instruction, 12*(4), 183-200. https://doi.org/10.29333/iji.2019.12412a

Farahani, A. A. K., Rezaee, A. A. & Zonouz, R. M. (2019). Motivational trajectories in language learning: Evidence from highly-motivated English as a foreign language learners. *Electronic Journal of Foreign Language Teaching, 16*(2), 281-299.

Farahani, A. A. K., Rezaee, A. A. & Zonouz, R. M. (2020). Exploring the development of writing complexity, accuracy, and fluency in relation to the motivational trajectories: A dynamically-oriented case study. *English Teaching & Learning, 44*, 81–100. https://doi.org/10.1007/s42321-019-00040-3

Feryok, A. & Oranje, J. (2015). Adopting a cultural portfolio project in teaching German as a foreign language: Language teacher cognition as a dynamic system. *The Modern Language Journal, 99*, 546-564. https://doi.org/10.1111/modl.12243

Fogal, G. (2022). System mapping simplex spaces: facilitating change in L2 educational contexts from a complexity theory perspective. *International Review of Applied Linguistics in Language Teaching, 60*(1), 103-121. https://doi.org/10.1515/iral-2021-0027

Fogal, G. G. & Koyama, D. (2022). A study of co-adaptation through journaling. *Journal of Second Language Writing. 55,* 100873. https://doi.org/10.1016/j.jslw.2022.100873

Fogal, G. G. (2019). Tracking microgenetic changes in authorial voice development from a complexity theory perspective. *Applied Linguistics, 40,* 432-455. https://doi.org/10.1093/applin/amx031

Fogal, G. G. (2020). Investigating variability in l2 development: Extending a complexity theory perspective on l2 writing studies and authorial voice. *Applied Linguistics, 41*(4), 575-600. https://doi.org/10.1093/applin/amz005

Fraschini, N. (2022). Language learners' emotional dynamics: Insights from a q methodology intensive single-case study. *Language, Culture and Curriculum, 36,* 222-239. https://doi.org/10.1080/07908318.2022.2133137

Fukui, H. & Yashima, T. (2021). Exploring evolving motivation to learn two languages simultaneously in a study-abroad context. *The Modern Language Journal, 105,* 267-293. https://doi.org/10.1111/modl.12695

Gao, Z. & Yuan, R. (2021). Understanding professional vulnerability in an era of performativity: Experiences of EFL academics in mainland China. *Teaching in Higher Education.* https://doi.org/10.1080/13562517.2021.1989577

Gheitasi, P., Lindgren, E. & Enever, J. (2022). The dynamics of foreign language values in Sweden: A social history. *CEPS Journal, 12,* 125-146. https://doi.org/10.26529/cepsj.758

Göpferich, S. (2013). Translation competence. Explaining development and stagnation from a dynamic systems perspective. *Target-international Journal of Translation Studies, 25,* 61-76. https://doi.org/10.1075/TARGET.25.1.06GOE

Gui, M., Chen, X. & Verspoor, M. H. (2021). The dynamics of reading development in L2 English for academic purposes. *System, 100,* 102546. https://doi.org/10.1016/j.system.2021.102546

Guo, Y. & Chen, H. (2020). A multidimensional development study of written English complexity of high-level non-English major students. *English Language Teaching, 13,* 156-162. https://doi.org/10.5539/elt.v13n1p156

Guo, Y., Xu, J. & Xu, X. (2020). An investigation into EFL learners' motivational dynamics during a group communicative task: A classroom-based case study. *System, 89,* 102214. https://doi.org/10.1016/j.system.2020.102214

Gürsoy, S. & Şahinkarakaş, Ş. (2019). The dynamic development of student immunity in language learning motivation. *Folklor/Edebiyat, 25,* 381-401. https://doi.org/10.22559/folklor.949

Haga, E. & Reinders, H. (2021). "Bad, really really bad" ESL learners' emotions and emotion regulation in response to native speaker feedback. *English Teaching & Learning, 45,* 245–262. https://doi.org/10.1007/s42321-021-00080-8

Han, J. & Hiver, P. (2018). Genre-based L2 writing instruction and writing-specific psychological factors: The dynamics of change. *Journal of Second Language Writing, 40,* 44-59. https://doi.org/10.1016/j.jslw.2018.03.001

Hassaskhah, J., Mahdavi Zafarghandi, A. & Fazeli, M. (2015). Reasons for demotivation across years of study: Voices from Iranian English major students. *Educational Psychology, 35,* 557-577. https://doi.org/10.1080/01443410.2014.893557

He, X., Zhou, D. & Zhang, X. (2021). An empirical study on Chinese university students' English language classroom anxiety with the idiodynamic approach. *SAGE Open.* https://doi.org/10.1177/21582440211037676

Heift, T. (2008). Modeling learner variability in CALL. *Computer Assisted Language Learning, 21,* 305-321. https://doi.org/10.1080/09588220802343421

Henry, A. (2020). Learner–environment adaptations in multiple language learning: Casing the ideal multilingual self as a system functioning in context. *International Journal of Multilingualism, 20*(2), 97-114. https://doi.org/10.1080/14790718.2020.1798969

Henry, A., Thorsen, C. & MacIntyre, P. D. (2021). Willingness to communicate in a multilingual context: Part one, a time-serial study of developmental dynamics. *Journal of Multilingual and Multicultural Development.* https://doi.org/10.1080/01434632.2021.1931248

Hofer, B. K. (2017). Emergent multicompetence at the primary level: A dynamic conception of multicompetence. *Language Awareness, 26,* 112-96. https://doi.org/10.1080/09658416.2017.1351981

Hsieh, Y. (2016). An exploratory study on Singaporean primary school students' development in Chinese writing. *The Asia-Pacific Education Researcher, 25,* 541-548. https://doi.org/10.1007/s40299-016-0279-0

Huang, T., Steinkrauss, R. & Verspoor, M. (2021). Variability as predictor in L2 writing proficiency. *Journal of Second Language Writing 52*(4), 100787. https://doi.org/10.1016/j.jslw.2020.100787

Huang, T., Steinkrauss, R. & Verspoor, M. H. (2022). Learning an L2 and L3 at the same time: Help or hinder? *International Journal of Multilingualism, 19,* 566-582. https://doi.org/10.1080/14790718.2020.1779726

Huang, T., Steinkrauss, R. & Verspoor, M.H. (2021). The emergence of the multilingual motivational system in Chinese learners. *System, 100,* 102564. https://doi.org/10.1016/j.system.2021.102564

Huynh, T. L. (2021). A complex dynamic systems approach to foreign language learners' anxiety in the emergency online language classrooms. *CALL-EJ, 22*(3), 200-229.

Jung, D., DiBartolomeo, M., Melero-García, F., Giacomino, L., Gurzynski-Weiss, L., Henderson, C. & Hidalgo, M. Á. (2020). Tracking the dynamic nature of learner individual differences: Initial results from a longitudinal study. *Studies in Second Language Learning and Teaching, 10,* 177-219. https://doi.org/10.14746/ssllt.2020.10.1.9

Jurkovič, V. (2019). Online informal learning of English through smartphones in Slovenia. *System, 80*, 27-37. https://doi.org/10.1016/j.system.2018.10.007

Kalantari, R. & Gholami, J. (2017). Lexical complexity development from dynamic systems theory perspective: Lexical density, diversity, and sophistication. *International Journal of Instruction, 10*(4), 1-18. https://doi.org/10.12973/iji.2017.1041a

Kan, P. F. (2014). Novel word retention in sequential bilingual children. *Journal of Child Language, 41*, 416-438. https://doi.org/10.1017/S0305000912000761

Karimi, M. N. & Nazari, M. (2021). Examining L2 teachers' critical incidents: A complexity theoretic perspective. *Innovation in Language Learning and Teaching, 15,* 81-98. https://doi.org/10.1080/17501229.2019.1676755

Kasbi, S. & Elahi Shirvan, M. (2017). Ecological understanding of foreign language speaking anxiety: Emerging patterns and dynamic systems. *Asian-Pacific Journal of Second and Foreign Language Education, 2*, 1-20. https://doi.org/10.1186/s40862-017-0026-y

Keijzer, M. (2010). The regression hypothesis as a framework for first language attrition. *Bilingualism: Language and Cognition, 13,* 9-18. https://doi.org/10.1017/S1366728909990356

Kikuchi, K. (2017). Reexamining demotivators and motivators: A longitudinal study of Japanese freshmen's dynamic system in an EFL context. *Innovation in Language Learning and Teaching, 11*, 128-145. https://doi.org/10.1080/17501229.2015.1076427

Kim, Y., Jung, Y. J. & Tracy-Ventura, N. (2017). Implementation of a localized task-based course in an EFL context: A study of students' evolving perceptions. *TESOL Quarterly, 51*, 632-660. https://doi.org/10.1002/tesq.381

King, J. (2013). Silence in the second language classrooms of Japanese universities. *Applied Linguistics, 34,* 325-343. https://doi.org/10.1093/APPLIN/AMS043

Kiss, T. & Pack, A. (2022). A network analysis of L2 motivational factors: Structure, connectivity, and central relational links. *TESOL Quarterly, 57*(2), 537-565. https://doi.org/10.1002/tesq.3166

Kliesch, M. and Pfenninger, S. E. (2021). Cognitive and socioaffective predictors of l2 microdevelopment in late adulthood: A longitudinal intervention study. *The Modern Language Journal, 105*, 237-266. https://doi.org/10.1111/modl.12696

Kliesch, M., Pfenninger, S. E., Wieling, M., Stark, E. & Meyer, M. (2021). Cognitive benefits of learning additional languages in old adulthood? Insights from an intensive longitudinal intervention study. *Applied Linguistics, 43*(4), 653-676. https://doi.org/10.1093/applin/amab077

Kopečková, R., Marecka, M., Wrembel, M. & Gut, U. (2016). Interactions between three phonological subsystems of young multilinguals: The influence of language status. *International Journal of Multilingualism, 13,* 426-443. https://doi.org/10.1080/14790718.2016.1217603

Koster, D. (2015). A dynamic, usage-based approach to teaching L2 Dutch. *Dutch Journal of Applied Linguistics, 4*(2), 257-264. https://doi.org/10.1075/dujal.4.2.08kos

Kostoulas, A., Stelma, J., Mercer, S., Cameron, L. & Dawson, S. (2018). Complex systems theory as a shared discourse space for TESOL. *TESOL Journal, 9*, 246-260. https://doi.org/10.1002/tesj.317

Kowal, I. (2014). Fluency in second language writing: A developmental perspective. *Studia Linguistica Universitatis Iagellonicae Cracoviensis, 131,* 229-246. https://doi.org/10.4467/20834624SL.14.013.2321

Kruk, M. & Zawodniak, J. (2019). On the possible interactions of varied EFL activities and learning styles with EFL students' motivational changes. *Innovation in Language Learning and Teaching, 13*, 178-193. https://doi.org/10.1080/17501229.2017.1420654

Kruk, M. (2019). Dynamicity of perceived willingness to communicate, motivation, boredom and anxiety in second life: The case of two advanced learners of English. *Computer Assisted Language Learning, 35*, 190-216. https://doi.org/10.1080/09588221.2019.1677722

Kruk, M., Pawlak, M., Elahi Shirvan, M., Taherian, T. & Yazdanmehr, E. (2022). A longitudinal study of foreign language enjoyment and boredom: A latent growth curve modeling. *Language Teaching Research.* https://doi.org/10.1177/13621688221082303

Kusyk, M. (2017). The development of complexity, accuracy and fluency in L2 written production through informal participation in online activities. *The CALICO Journal, 34*, 75-96. https://doi.org/10.1558/cj.29513

Lasagabaster, D. (2017). Pondering motivational ups and downs throughout a two-month period: A complex dynamic system perspective. *Innovation in Language Learning and Teaching, 11*, 109-127. https://doi.org/10.1080/17501229.2015.1073734

Lenzing, A. (2015). Exploring regularities and dynamic systems in L2 development. *Language Learning, 65,* 89-122. https://doi.org/10.1111/lang.12092

Lesonen, S., Steinkrauss, R., Suni, M. & Verspoor, M. H. (2021). Dynamic usage-based principles in the development of L2 Finnish evaluative constructions. *Applied Linguistics, 42*(3), 442-472. https://doi.org/10.1093/applin/amaa030

Lesonen, S., Suni, M., Steinkrauss, R. & Verspoor, M.H. (2018). From conceptualization to constructions in Finnish as an L2: A case study. *Pragmatics & Cognition, 24*, 212-262. https://doi.org/10.1075/pc.17016.les

Li, C., Dewaele, J. & Jiang, G. (2019). The complex relationship between classroom emotions and EFL achievement in China. *Applied Linguistics Review, 11*, 485-510. https://doi.org/10.1515/applirev-2018-0043

Li, C., Zhou, C. & Zhang, W. (2022). The impact of an intensive English reading course based on the production-oriented approach on the L2 motivational self system among Chinese university English majors from a dynamic systems theory perspective. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.761093

Liu, D. (2021). Prosody transfer failure despite cross-language similarities. *Journal of Second Language Pronunciation, 7*(1), 38-61. https://doi.org/10.1075/jslp.18047.liu

Liu, J. (2022). A dynamic approach to understanding motivation in an interpreting course. *Language Sciences, 92*, 101472. https://doi.org/10.1016/j.langsci.2022.101472

Liu, Z. (2022). Introducing a multimodal perspective to emotional variables in second language acquisition education: Systemic functional multimodal discourse analysis. *Frontiers in Psychology, 13*, 1016442. https://doi.org/10.3389/fpsyg.2022.1016441

Lou, N., Chaffee, K. & Noels, K. (2022). Growth, fixed, and mixed mindsets: Mindset system profiles in foreign language learners and their role in engagement and achievement. *Studies in Second Language Acquisition, 44*(3), 607-632. https://doi.org/10.1017/S0272263121000401

Lowie, W. & Verspoor, M. H. (2019). Individual differences and the ergodicity problem. *Language Learning, 69*(s1), 184-206. https://doi.org/10.1111/lang.12324

Lowie, W., van Dijk, M., Chan, H. & Verspoor, M. H. (2017). Finding the key to successful L2 learning in groups and individuals. *Studies in Second Language Learning and Teaching, 7*, 127-148. https://doi.org/10.14746/ssllt.2017.7.1.7

Luo, X. (2022). The effect of manipulating task complexity along resource-dispersing dimension on L2 written performance from the perspective of complexity theory. *English Language Teaching, 15*(9), 151-159. https://doi.org/10.5539/elt.v15n9p151

MacIntyre, P. D. & Legatto, J. J. (2011). A dynamic system approach to willingness to communicate: Developing an idiodynamic method to capture rapidly changing affect. *Applied Linguistics, 32*, 149-171. https://doi.org/10.1093/applin/amq037

MacIntyre, P. D. & Wang, L. (2021). Willingness to communicate in the L2 about meaningful photos: Application of the pyramid model of WTC. *Language Teaching Research, 25*, 878-898. https://doi.org/10.1177/13621688211004645

Martin, B. (2012). Coloured language: Identity perception of children in bilingual programmes. *Language Awareness, 21*, 33-56. https://doi.org/10.1080/09658416.2011.639888

Mercer, S. (2011). Language learner self-concept: Complexity, continuity and change. *System, 39*(3), 335-346. https://doi.org/10.1016/j.system.2011.07.006

Mercer, S. (2011). Understanding learner agency as a complex dynamic system. *System, 39*, 427-436. https://doi.org/10.1016/j.system.2011.08.001

Mroz, A. & Thrasher, T. (2022). Proficiency development and smartphone usage in study abroad: Microgenetic longitudinal case studies of French learners. *Foreign Language Annals, 55*(2), 455-493. https://doi.org/10.1111/flan.12619

Mroz, A. & Thrasher, T. (2022). Unfolding of COVID-19 crisis in a study-abroad program: voices of stakeholders involved in the evacuation. *Frontiers: The Interdisciplinary Journal of Study Abroad, 34*(2), 27-55. https://doi.org/10.36366/frontiers.v34i2.568

Nekrasova-Beker, T. (2016). EFL learners' use of question constructions over time: Patterns and proficiency effects. *System, 58*, 82-96. https://doi.org/10.1016/j.system.2016.03.004

Nematizadeh, S. & Wood, D. R. (2019). Willingness to communicate and second language speech fluency: An investigation of affective and cognitive dynamics. *The Canadian Modern Language Review, 75*(3), 197-215. https://doi.org/10.3138/cmlr.2017-0146

Nematizadeh, S. (2021). Willingness to communicate and second language speech fluency: An idiodynamic investigation of attractor states. *Journal for the Psychology of Language Learning, 3*(1), 26-49. http://www.jpll.org/index.php/journal/article/view/snematiz

O'Leary, J.A., & Steinkrauss, R. (2022). Syntactic and lexical complexity in L2 English academic writing: Development and competition. *Ampersand, 9,* 100096. https://doi.org/10.1016/j.amper.2022.100096

Opitz, C. (2013). A dynamic perspective on late bilinguals' linguistic development in an L2 environment. *International Journal of Bilingualism, 17*, 701-715. https://doi.org/10.1177/1367006912454621

Pack, A., Kiss, T., Barrett, A. J. & Chen, C. (2022). Towards a non-dichotomous view of motivators and demotivators in language learning. *International Journal of Applied Linguistics, 32*(1), 94-107. https://doi.org/10.1111/ijal.12397

Papi, M. & Hiver, P. (2020). Language learning motivation as a complex dynamic system: A global perspective of truth, control, and value. *The Modern Language Journal*, *104*, 209-232. https://doi.org/10.1111/modl.12624

Pawlak, M., Mystkowska-Wiertelak, A. & Bielak, J. (2016). Investigating the nature of classroom willingness to communicate (WTC): A micro-perspective. *Language Teaching Research, 20*, 654-671. https://doi.org/10.1177/1362168815609615

Peng, H., W. Lowie & S. Jager. (2022). Unravelling the idiosyncrasy and commonality in L2 developmental processes: A time-series clustering methodology. *Applied Linguistic 43*(5), 891-911. https://doi.org/10.1093/applin/amac011

Pfenninger, S. E. (2021). About the inter and the intra in age-related research: Evidence from a longitudinal CLIL study with dense time serial measurements. *Linguistics Vanguard, 7*(s2), 20200028. https://doi.org/10.1515/lingvan-2020-0028

Pfenninger, S. E. (2022). Emergent bilinguals in a digital world: A dynamic analysis of long-term L2 development in (pre)primary school children. *International Review of Applied Linguistics in Language Teaching, 60*, 41-66. https://doi.org/10.1515/iral-2021-0025

Pham, G. T. (2016). Pathways for learning two languages: Lexical and grammatical associations within and across languages in sequential bilingual children. *Bilingualism, 19*(5), 928-938. https://doi.org/10.1017/S1366728915000899

Polat, B. & Kim, Y. J. (2014). Dynamics of complexity and accuracy: A longitudinal case study of advanced untutored development. *Applied Linguistics, 35*, 184-207. https://doi.org/10.1093/applin/amt013

Porretta, V., Tucker, B. V. & Järvikivi, J. (2016). The influence of gradient foreign accentedness and listener experience on word recognition. *Journal of Phonetics, 58,* 1-21. https://doi.org/10.1016/j.wocn.2016.05.006

Poupore, G. (2018). A complex systems investigation of group work dynamics in l2 interactive tasks. *The Modern Language Journal, 102*, 350-370. https://doi.org/10.1111/modl.12467

Qi, G. Y. & Wang, Y. (2022). Challenges and responses: A complex dynamic systems approach to exploring language teacher agency in a blended classroom. *The JALT CALL Journal, 18*(1), 54–82. https://doi.org/10.29140/jaltcall.v18n1.569

Qian, Y. (2022). Dynamism of collocation in L2 English writing: A bigram-based study. *International Review of Applied Linguistics in Language Teaching, 60*, 339-362. https://doi.org/10.1515/iral-2019-0012

Rahman, M. M. & Singh, M. K. (2021). Complex dynamic systems of language teacher cognitions: A case study from Bangladesh. *Issues in Educational Research, 31*(1), 241-245.

Ratih, K., Kurniawan, F. A., Nurhidayat, N., Prayitno, H. J. & Buan, A. T. (2021). Challenges and adjustments in undertaking teaching practice across countries in disruptive era of education. *Asian Journal of University Education, 17*(4). https://doi.org/10.24191/ajue.v17i4.16206

Ritzau, U. (2014). A qualitative investigation of the dynamics and complexity of language learner beliefs through written protocols. *Linguistik Online, 61*, 97-111. https://doi.org/10.13092/LO.61.1278

Roehr-Brackin, K. (2014). Explicit knowledge and processes from a usage-based perspective: The developmental trajectory of an instructed L2 learner. *Language Learning, 64*, 771-808. https://doi.org/10.1111/lang.12081

Rokoszewska, K. J. (2020). Intra-individual variability in the emergence of lexical complexity in speaking English at secondary school - A case study of a good, average, and poor language learner. *Theory and Practice of Second Language Acquisition, 6*(1), 107-142. https://doi.org/10.31261/TAPSLA.7929

Rokoszewska, K. J. (2022). The dynamics of monthly growth rates in the emergence of complexity, accuracy, and fluency in L2 English writing at secondary school - A learner corpus analysis. *System, 106,* 102775. https://doi.org/10.1016/j.system.2022.102775

Rosmawati (2014). Dynamic development of complexity and accuracy: A case study in second language academic writing. *Australian Review of Applied Linguistics, 37*, 75-100. https://doi.org/10.1075/aral.37.2.01ros

Rostami, F. & Yousefi, M. H. (2020). Iranian novice English teachers' agency construction: The complexity dynamic/system perspective. *Asian-Pacific Journal of Second and Foreign Language Education, 5*, 1-16. https://doi.org/10.1186/s40862-020-00082-2

Ruck, J. (2020). Multilingualism and affective attitudes: The sociocognitive profiles of first-year learners of L2 German. *Die Unterrichtspraxis/Teaching German, 53*, 210-228. https://doi.org/10.1111/tger.12137

Sahin, I. & Yildırım, A. (2016). Transforming professional learning into practice. *ELT Journal, 70*, 241-252. https://doi.org/10.1093/elt/ccv070

Sak, M. (2022). Dynamicity of language teacher motivation in online EFL classes. *System, 111,* 102948. https://doi.org/10.1016/j.system.2022.102948

Sampson, R. J. & Yoshida, R. (2020). Emergence of divergent L2 feelings through the co-adapted social context of online chat. *Linguistics and Education, 60*, 100861. https://doi.org/10.1016/j.linged.2020.100861

Sampson, R. J. (2015). Tracing motivational emergence in a classroom language learning project. *System, 50*, 10-20. https://doi.org/10.1016/j.system.2015.03.001

Sampson, R. J. (2016). EFL teacher motivation in-situ: Co-adaptive processes, openness and relational motivation over interacting timescales. *Studies in Second Language Learning and Teaching, 6*, 293-318. https://doi.org/10.14746/ssllt.2016.6.2.6

Sampson, R. J. (2019). Real people with real experiences: The emergence of classroom L2 study feelings over interacting timescales. *System, 84*, 14-23. https://doi.org/10.1016/j.system.2019.05.001

Selçuk, Ö., & Erten, İ. H. (2017). A display of patterns of change in learners' motivation: Dynamics perspective. *Novitas-ROYAL (Research on Youth and Language), 11*(2), 128-141. https://files.eric.ed.gov/fulltext/EJ1171147.pdf

Serafini, E. J. (2017). Exploring the dynamic long-term interaction between cognitive and psychosocial resources in adult second language development at varying proficiency. *The Modern Language Journal, 101*, 369-390. https://doi.org/10.1111/modl.12400

Smit, N., van Dijk, M., de Bot, K. & Lowie, W. (2022). The complex dynamics of adaptive teaching: Observing teacher-student interaction in the language classroom. *International Review of Applied Linguistics in Language Teaching, 60,* 23-40. https://doi.org/10.1515/IRAL-2021-0023

Smith, L., & King, J. (2017). A dynamic systems approach to wait time in the second language classroom. *System, 68,* 1-14. https://doi.org/10.1016/J.SYSTEM.2017.05.005

Sockett, G. & Toffoli, D. (2012). Beyond learner autonomy: A dynamic systems view of the informal learning of English in virtual online communities. *ReCALL, 24*, 138-151. https://doi.org/10.1017/S0958344012000031

Sockett, G. (2013). Understanding the online informal learning of English as a complex dynamic system: An emic approach. *ReCALL, 25,* 48-62. https://doi.org/10.1017/S095834401200033X

Soltani, S. & Mohseni, A. (2022). A psycho-socio-cultural approach towards technology-assisted language teaching: Nonlinear dynamic l2 motivation theory. *Computer Assisted Language Learning Electronic Journal, 23*(3), 24-40. http://callej.org/journal/23-3/Soltani-Mohseni2022.pdf

Spoelman, M. & Verspoor, M. (2010). Dynamic patterns in development of accuracy and complexity: A longitudinal case study in the acquisition of Finnish. *Applied Linguistics, 31*(4), 532-553. https://doi.org/0.1093/applin/amq001

Stotz, Q. & Cardoso, W. (2022). Applying complex dynamic systems theory to identify dynamic properties of plurilingual repertoires. *TESL Canada Journal, 38*(2), 140–170. https://doi.org/10.18806/tesl.v38i2.1360

Strugielska, A., Guttfeld, D. & Linke-Ratuszny, M. (2021). Teaching foreign languages in higher education during the corona crisis. *XLinguae, 14*(1), 228-248. https://doi.org/10.18355/XL.2021.14.01.18

Sulis, G., Mercer, S., Mairitsch, A., Babic, S. & Shin, S. (2021). Pre-service language teacher wellbeing as a complex dynamic system. *System, 103*, 102642. https://doi.org/10.1016/j.system.2021.102642

Sun, H. (2020). Unpacking reading text complexity: A dynamic language and content approach. *Studies in Applied Linguistics & TESOL, 20*(2), 1-20. https://doi.org/10.7916/salt.v20i2.7098

Sun, H., Steinkrauss, R., Steen, S. V., Cox, R. F. & de Bot, K. (2016). Foreign language learning as a complex dynamic process: A microgenetic case study of a Chinese child's English learning trajectory. *Learning and Individual Differences, 49*, 287-296. https://doi.org/10.1016/j.lindif.2016.05.010

Sun, Q. & Zhang, L. J. (2022). Understanding novice and experienced teachers' cognitions and practices for sustainable teacher development: The case of form-focused instruction in English language teaching. *Sustainability, 14*(8), 4711. https://doi.org/10.3390/su14084711

Syed, H. & Kuzborska, I. (2019). Understanding the nature of variations in postgraduate learners' willingness to communicate in English. *Cogent Education, 6*(1), 1606487. https://doi.org/10.1080/2331186X.2019.1606487

Syed, H. & Kuzborska, I. (2020). Dynamics of factors underlying willingness to communicate in a second language. *The Language Learning Journal, 48*, 481-500. https://doi.org/10.1080/09571736.2018.1435709

Thompson, A. S. & Aslan, E. (2015). Multilingualism, perceived positive language interaction (PPLI), and learner beliefs: What do Turkish students believe? *International Journal of Multilingualism, 12*, 259-275. https://doi.org/10.1080/14790718.2014.973413

Thompson, A. S. (2017). Don't tell me what to do! The anti-ought-to self and language learning motivation. *System, 67*, 38-49. https://doi.org/10.1016/j.system.2017.04.004

van Horn, J. (2017). Exploring the dynamism between propositional complexity and error rate: A case study. *Studies in Applied Linguistics & TESOL, 17*(1), 12-23. https://doi.org/10.7916/salt.v17i1.1235

Verspoor, M. H. & Hồng, N. T. (2013). A dynamic usage-based approach to communicative language teaching. *European Journal of Applied Linguistics, 1*(1), 22-54. https://doi.org/10.1515/eujal-2013-0003

Verspoor, M. H., Lowie, W. & van Dijk, M. (2008). Variability in second language development from a dynamic systems perspective. *IEEE Transactions on Circuits and Systems I-regular Papers, 92*(2), 214-231. https://doi.org/10.1111/j.1540-4781.2008.00715.x

Verspoor, M. H., Schmid, M. S. & Xu, X. (2012). A dynamic usage based perspective on L2 writing. *Journal of Second Language Writing, 21*, 239-263. https://doi.org/10.1016/j.jslw.2012.03.007

Viswanathan, U. (2019). Understanding the relationship between second language teacher beliefs and their instructional practices: A case study of core French teachers. *Canadian Journal of Applied Linguistics, 22*(1), 26-59. https://doi.org/10.7202/1060905ar

Wang, R. (2022). Enjoymeter for exploring micro-scale changes in foreign language enjoyment. *Frontiers in Psychology, 13,* 882748. https://doi.org/10.3389/fpsyg.2022.882748

Wang, R., Elahi Shirvan, M. & Taherian, T. (2021). Perseverance of effort and consistency of interest: A longitudinal perspective. *Frontiers in Psychology, 12,* 743414. https://doi.org/10.3389/fpsyg.2021.743414

Wang, Z. (2022). Dynamic development of syntactic complexity in second language writing: A longitudinal case study of a young Chinese EFL learner. *Frontiers in Psychology, 13.* https://doi.org/10.3389/fpsyg.2022.974481

Waninge, F., Dörnyei, Z. & de Bot, K. (2014). Motivational dynamics in language learning: Change, stability, and context. *The Modern Language Journal, 98,* 704-723. https://doi.org/10.1111/modl.12118

Wind, A. M. (2021). Nonlinearity and inter- and intra-individual variability in the extent of engagement in self-reflection and its role in second language writing: A multiple-case study. *System,* 102672. https://doi.org/10.1016/j.system.2021.102672

Wood, D. R. (2016). Willingness to communicate and second language speech fluency: An idiodynamic investigation. *System, 60,* 11-28. https://doi.org/10.1016/j.system.2016.05.003

Xiang, X., Chang, P. & Yu, B. (2022). Exploring an EAP writing teacher's adaptive expertise and adaptive teaching practices from a CDST perspective. *Frontiers in Psychology*, *13.* https://doi.org/10.3389/fpsyg.2022.957429

Xiao, H., Dai, C. & Dong, L. (2021). The development of interlanguage pragmatic markers in alignment with role relationships. *Pragmatics, 31*(4), 617-646. https://doi.org/10.1075/prag.20013.xia

Yaghoubinejad, H., Zarrinabadi, N. & Ketabi, S. (2017). Fluctuations in foreign language motivation: An investigation into Iranian learners' motivational change over time. *Current Psychology, 36,* 781-790. https://doi.org/10.1007/s12144-016-9467-6

Yashima, T., MacIntyre, P. D. & Ikeda, M. (2018). Situated willingness to communicate in an L2: Interplay of individual characteristics and context. *Language Teaching Research, 22,* 115-137. https://doi.org/10.1177/1362168816657851

Yu, H. & Lowie, W. (2020). Dynamic paths of complexity and accuracy in second language speech: A longitudinal case study of Chinese learners. *Applied Linguistics, 41*(6), 855-877. https://doi.org/10.1093/applin/amz040

Yu, H., Lowie, W. & Peng, H. (2022). Understanding salient trajectories and emerging profiles in the development of Chinese learners' motivation: A growth mixture modeling approach. *International Review of Applied Linguistics in Language Teaching.* https://doi.org/10.1515/iral-2022-0036

Yu, H., Peng, H. & Lowie, W. (2022). Dynamics of language learning motivation and emotions: A parallel-process growth mixture modeling approach. *Frontiers in Psychology, 13.* https://doi.org/10.3389/fpsyg.2022.899400

Yu, S., Xu, H., Jiang, L. & Chan, I. K. (2020). Understanding Macau novice secondary teachers' beliefs and practices of EFL writing instruction: A complexity theory perspective. *Journal of Second Language Writing, 48*, 100728. https://doi.org/10.1016/j.jslw.2020.100728

Yu, Z. & Dong, Y. (2022). The emergence of a complex language skill: Evidence from the self-organization of interpreting competence in interpreting students. *Bilingualism: Language and Cognition, 25,* 269-282. https://doi.org/10.1017/S1366728921000870

Yuan, R. & Yang, M. (2022), Unpacking language teacher educators' expertise: A complexity theory perspective. *TESOL Quarterly*, *56*, 656-687. https://doi.org/10.1002/tesq.3088

Yuan, R., Zhang, J. & Yu, S. (2018). Understanding teacher collaboration processes from a complexity theory perspective: A case study of a Chinese secondary school. *Teachers and Teaching, 24,* 520-537. https://doi.org/10.1080/13540602.2018.1447458

Zein, M. S. (2016). Government-based training agencies and the professional development of Indonesian teachers of English for young learners: Perspectives from complexity theory. *Journal of Education for Teaching, 42*, 205-223. https://doi.org/10.1080/02607476.2016.1143145

Zhang, J. & Lu, X. (2013). Variability in Chinese as a foreign language learners' development of the Chinese numeral classifier system. *The Modern Language Journal, 97,* 46-60. https://doi.org/10.1111/j.1540-4781.2012.01423.x

Zhang, L. J. (2010). A dynamic metacognitive systems account of Chinese university students' knowledge about EFL reading. *TESOL Quarterly, 44*, 320-353. https://doi.org/10.5054/tq.2010.223352

Zhang, S., Zhang, H. & Zhang, C. (2022). A dynamic systems study on complexity, accuracy, and fluency in english writing development by Chinese university students. *Frontiers in Psychology, 13,* 787710. https://doi.org/10.3389/fpsyg.2022.787710

Zheng, H. (2013). Teachers' beliefs and practices: A dynamic and complex relationship. Asia-Pacific *Journal of Teacher Education, 41*, 331-343. https://doi.org/10.1080/1359866X.2013.809051

Zheng, H. (2013). The dynamic interactive relationship between Chinese secondary school EFL teachers' beliefs and practice. *The Language Learning Journal, 41,* 192-204. https://doi.org/10.1080/09571736.2013.790133

Zheng, Y. (2016). The complex, dynamic development of L2 lexical use: A longitudinal study on Chinese learners of English. *System, 56*, 40-53. https://doi.org/10.1016/j.system.2015.11.007

Zheng, Y., Lu, X. & Ren, W. (2020). Tracking the evolution of Chinese learners' multilingual motivation through a longitudinal q methodology. *The Modern Language Journal, 104,* 781-803. https://doi.org/10.1111/modl.12672

Zhou, S. A., Hiver, P. & Zheng, Y. (2022). Modeling intra- and inter- individual changes in L2 classroom engagement. *Applied Linguistics,* amac065. https://doi.org/10.1093/applin/amac065