

Research on the Cognitive Mechanism and Teaching Optimization of Second Language Acquisition Empowered by Intelligent Technology

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ABSTRACT Against the background of rapid iteration in artificial intelligence, big data, natural language processing, machine learning, and deep digital transformation in education, the research and teaching paradigms of second language acquisition are undergoing structural change. The essence of second language acquisition is a complex cognitive process involving perceptual attention, memory encoding, rule internalization, semantic construction, logical deduction, crosscultural integration, and communicative output. Traditional research and teaching approaches often have difficulty capturing implicit cognitive processes, dynamic acquisition evolution, and individual cognitive differences. This study analyzes how intelligent technology empowers the cognitive mechanisms and teaching optimization of second language acquisition. It defines an intelligent-technology cluster including NLP, AI speech evaluation, eye tracking, EEG observation, learning analytics, and adaptive learning systems, and explains its role in explicit cognitive observation, dynamic tracking, personalized diagnosis, and cognitive-adaptive teaching. In smart learning environments, wireless learning systems, signal acquisition devices, and electromagnetic-compatible terminals provide the technical basis for collecting and transmitting learning data. The study proposes a teaching optimization path of cognitive diagnosis, hierarchical supply, adaptive feedback, and communicative output training.

INDEX TERMS second language acquisition, intelligent technology, cognitive mechanism, learning signal acquisition, wireless learning systems

I. INTRODUCTION

A. RESEARCH BACKGROUND AND SIGNIFICANCE

1) Digital Education and Intelligent Technology Empowering the Wave of Language Education in the Era

CURRENTLY, the systemic integration of artificial intelligence within pedagogical frameworks has reached a stage of substantive application. China's "Education Informatization 2.0 Action Plan" and "Artificial Intelligence+Education Action Plan" clearly propose to reshape talent training models, subject teaching models, and academic research paradigms with intelligent technology, and promote the transformation of higher education and language education towards intelligence, personalization, precision, and cognition[1]. Second language acquisition, as a core research field in applied linguistics, foreign language education, and cognitive linguistics, is a core carrier for foreign language majors, public foreign language education, and cross-cultural talent cultivation in universities. It covers the entire process of learning, cognition, and teaching practice of various second languages such as English, Japanese,

and French[2].

2) Inherent Limitations of Research on Cognitive Mechanisms of Second Language Acquisition

Second language acquisition is a complex cognitive and psychological process that differs from native language acquisition[3]. It is not simply about memorizing and imitating language knowledge, but rather a closed-loop cognitive processing process in which learners complete language input, attention perception, memory encoding, rule induction, semantic construction, interlanguage reconstruction, communicative output, and cognitive correction based on their existing native language cognitive framework. It involves interdisciplinary fields such as cognitive psychology, psycholinguistics, neurolinguistics, and socio-cultural linguistics[4].

3) Mismatch Dilemma Between Traditional Second Language Teaching and Cognitive Needs

The traditional second language classroom teaching has long used a fixed model of “teacher lectures+knowledge imparting+mechanical exercises+final assessments”, which is frequently relies on a generalized instructional logic. While traditional methods like ‘scaffolding’ acknowledge cognitive development, they often struggle to provide the granular, real-time adaptation required to address the diverse internal cognitive mechanisms and individual differences of each learner at scale[5]. From the perspective of cognitive adaptation, the existing prominent problems are concentrated on four levels: first, homogenization of teaching supply, adopting unified teaching content, teaching progress, and training difficulty, ignoring individual cognitive differences in learners’ working memory, language perception, and rule induction, making it difficult to achieve personalized teaching; Secondly, there is a lack of cognitive diagnosis, and teachers are unable to accurately determine the cognitive barriers that learners face in second language acquisition, whether it is due to weak vocabulary memory, cognitive biases in syntactic rules, or insufficient semantic and logical construction, and can only rely on teaching experience to teach in a general manner; The third issue is the superficial lag in learning feedback[6]. Traditional homework grading and classroom questioning feedback only focus on the correctness of language knowledge, and cannot deeply analyze the causes of errors and cognitive processing loopholes at the cognitive level, making it difficult to achieve cognitive level correction and internalization; The fourth issue is insufficient cognitive activation. The classroom mainly focuses on passive knowledge reception, lacking activation and training of learners’ higher-order cognitive abilities such as attention perception, active induction, logical deduction, and creative language output, which hinders the deep development of second language acquisition[7].

4) The Inevitable Trend of Integrating Intelligent Technology with Second Language Cognition and Teaching

The maturity of intelligent technology provides a new tool and research paradigm for breaking through the limitations of cognitive research in second language acquisition and solving the dilemma of cognitive mismatch in teaching[8]. On the one hand, intelligent physiological observation technology, language big data, and AI algorithms can transform the cognitive process of second language acquisition from implicit unobservable to explicit quantifiable, traceable, and deconstructible, providing empirical data and technical means for the study of cognitive mechanisms; On the other hand, applications such as intelligent adaptive teaching, AI intelligent accompaniment, personalized cognitive training, and big data cognitive diagnosis can achieve the transformation of second language teaching from “unified indoctrination” to “cognitive adaptation, layered supply, precise coaching, and personalized optimization”, and build a new second language teaching system with learners’ cognitive mecha-

nisms as the core[9]. In this context, conducting research on the cognitive mechanisms and teaching optimization of second language acquisition empowered by intelligent technology is not only an academic demand for cross innovation between cognitive linguistics and intelligent education, but also a practical necessity for improving the quality and efficiency of second language teaching reform in the new era[10].

B. RESEARCH SIGNIFICANCE

1) Theoretical Significance

Firstly, reconstruct the theoretical framework of cognitive research on second language acquisition in the era of intelligence[11]. This article integrates cognitive psychology, classic theories of second language acquisition, and intelligent educational technology theory to define the connotation, dimensions, and mechanisms of intelligent technology intervention in second language acquisition cognitive processing[12]. It deconstructs the new operating rules of the five cognitive levels of perception, memory, rules, semantics, and communication empowered by intelligent technology, fills the theoretical gap of traditional second language acquisition cognitive research lacking the perspective of intelligent technology, and enriches the theoretical system of applied linguistics and cognitive linguistics[13].

Secondly, establish a theoretical model of the intrinsic correlation between intelligent technology, cognitive mechanisms, and teaching optimization. Clarify the logical relationship between how intelligent technology affects various cognitive processes in second language acquisition, how cognitive mechanisms determine learners’ acquisition patterns, and how teaching optimization adapts to cognitive traits, forming a closed-loop theoretical framework of “technology empowers cognition, cognition leads teaching, and teaching feeds back acquisition”, providing a theoretical paradigm for subsequent interdisciplinary research[14].

Thirdly, expand the methodological framework of cognitive empirical research. Introducing intelligent research methods such as eye tracking, EEG experiments, and learning big data mining[15], breaking through the limitations of traditional speculative research and small-scale questionnaire surveys, constructing a new paradigm for quantitative empirical research on second language acquisition cognitive mechanisms, and promoting the upgrading of second language acquisition research from qualitative speculation to quantitative observation, data verification, and dynamic tracking[16].

2) Practical Significance

Firstly, provide cognitive oriented intelligent optimization solutions for second language classroom teaching[17]. Based on the inherent cognitive mechanisms of second language acquisition and individual cognitive differences, feasible teaching goal reconstruction, content stratification supply, intelligent classroom mode, and cognitive evaluation feedback path are proposed to directly adapt to the reform

needs of second language classroom teaching in universities such as English and minority languages[18].

Secondly, assist teachers in achieving precise cognitive diagnosis and personalized teaching. By relying on intelligent technology tools, second language teachers can quickly identify students' cognitive shortcomings, interference from mother tongue transfer, and obstacles to rule internalization. Based on different cognitive traits, teaching tasks, training content, and coaching plans can be designed in a layered manner, truly achieving personalized teaching centered on cognition[19]. Thirdly, empower learners to acquire autonomous second language and enhance their cognitive abilities. The intelligent adaptive learning system, AI oral practice, and cognitive training resources can match learners' personal cognitive rhythm and ability shortcomings, guide learners to optimize memory strategies, rule induction strategies, and semantic construction strategies, and improve second language acquisition efficiency and comprehensive application ability from the cognitive bottom layer.

Fourthly, provide theoretical and demand support for the development of language based intelligent teaching platforms[20]. Clarify the technical adaptation requirements and teaching function requirements for each cognitive stage of second language acquisition, providing practical basis for the functional design, algorithm optimization, and resource push logic of intelligent language learning apps, adaptive second language teaching systems, and cognitive diagnosis platforms.

C. CURRENT RESEARCH STATUS AT HOME AND ABROAD

The research on the cognitive mechanism of second language acquisition in foreign countries started earlier, and has successively formed classic schools such as behaviorist acquisition theory, innate theory, cognitive acquisition theory, interlanguage theory, input hypothesis, interaction hypothesis, and socio-cultural cognitive theory. Early research focused on macro cognitive laws such as mother tongue transfer, language input, acquisition sequence, and interlanguage evolution, laying the theoretical foundation for the study of second language acquisition cognition.

At the level of cross disciplinary research between intelligent technology and second language cognition, developed countries in Europe and America rely on artificial intelligence and cognitive neuroscience technology to conduct empirical research. Firstly, they use ERP, fMRI EEG technology, and eye tracking technology to observe the brain cognitive activation areas and real-time attention allocation rules of second language vocabulary processing, syntactic parsing, and discourse reading, and deconstruct the differential mechanisms of second language and native language cognitive processing; Secondly, relying on learning analysis technology and big data, collecting online second language learning behavior data from learners, mining the correlation between learning strategies, acquisition habits, and cognitive efficiency, and dividing learners into different

cognitive types; The third is to develop an intelligent adaptive second language learning system, which dynamically adjusts the learning difficulty and content sequence based on cognitive characteristics such as learners' memory capacity, language perception speed, and rule induction ability, to achieve cognitive adaptive acquisition training; The fourth is to use natural language processing and AI oral evaluation technology to study the semantic cognitive construction rules behind oral output and writing representation, and accurately identify acquisition errors at the cognitive level.

Foreign research has formed a complete research chain of "cognitive neural observation big data behavior mining intelligent system adaptation teaching mode innovation", but research is mostly based on the Indo European language system and the cognitive characteristics of Western learners. Cognitive models and teaching adaptation strategies are difficult to directly adapt to the second language acquisition cognitive rules of Chinese native speakers in China, and localization reconstruction and adaptation are needed.

II. DEFINITION OF RELEVANT THEORETICAL FOUNDATIONS AND CORE CONCEPTS

A. DEFINITION OF CORE CONCEPTS

1) Intelligent Technology

The intelligent technology referred to in this article is an artificial intelligence technology cluster adapted to second language acquisition and teaching scenarios, covering natural language processing, AI speech recognition and oral evaluation, machine learning and big data learning analysis, eye tracking and cognitive neural observation technology, intelligent adaptive learning systems, intelligent human-computer interaction training, text semantic mining and grammar correction technology, etc. Different from traditional multimedia teaching technology, intelligent technology has the core abilities of autonomous learning, cognitive observation, behavior mining, personality adaptation, intelligent diagnosis, and dynamic deduction. By utilizing algorithmic modeling and physiological data tracking, these technologies facilitate the empirical quantification of implicit cognitive loads. This allows for the automated identification of rule-acquisition patterns and the algorithmic optimization of instructional content delivery, transitioning from speculative pedagogical design to data-verified cognitive intervention.

2) Second Language Acquisition

Second language acquisition refers to the entire process of learners receiving knowledge, internalizing rules, constructing language representations, and developing communicative abilities in the target language (English, Japanese, French, etc.) in a natural or classroom teaching environment after mastering the mother tongue system. It includes two forms of intentional classroom learning and unconscious natural acquisition, and is a complex process that combines language symbol learning, cognitive psychological processing, and socio-cultural integration. The core hallmark is

the formation, evolution, and gradual convergence of the interlanguage system towards the target language.

3) Cognitive Mechanisms

The cognitive mechanism of second language acquisition is the internal psychological and neural operation mechanism of the learner's brain, which processes second language input, processes language information, stores language representations, induces grammar rules, constructs semantic logic, completes language output and cognitive correction. It includes five core sub mechanisms: perceptual attention mechanism, working memory and long-term memory encoding mechanism, syntactic rule induction mechanism, semantic association construction mechanism, and cross-cultural communication cognitive inference mechanism. It has typical characteristics of implicit, dynamic, hierarchical, individual differences, and nonlinear evolution.

B. RESEARCH BASIC THEORY

1) Classic Theories of Second Language Acquisition

Interlanguage theory: Interlanguage is an independent language system between the learner's mother tongue and the target language, which constantly evolves with the acquisition process. Its development essence is a process of cognitive structure reconstruction and rule revision, and it is the core theoretical basis for deconstructing the dynamic evolution law of second language acquisition cognition in this article.

Input hypothesis and output hypothesis: The input hypothesis emphasizes that comprehensible language input is a prerequisite for second language acquisition, while the output hypothesis advocates that language communicative output forces semantic construction and rule internalization at the cognitive level, providing theoretical support for intelligent technology to optimize language input supply and design intelligent communicative output tasks.

Interaction hypothesis: The negotiation of meaning and feedback correction in language interaction can promote the deepening of cognitive processing, providing a theoretical basis for the design of intelligent human-computer interaction, AI classroom interaction, and intelligent training modes.

2) Cognitive Processing Theory

The cognitive processing theory divides human learning cognition into a complete process of perceptual attention, information encoding, memory storage, retrieval and application, and cognitive correction. It believes that learning is essentially a multi-level cognitive processing of information. This theory is perfectly adapted to the entire process of second language acquisition, providing a core theoretical framework for dividing this article into five cognitive levels and deconstructing the empowering role of intelligent technology in various cognitive processing stages.

3) Cognitive Style and Individual Differences Theory

This theory suggests that learners have stable individual differences in cognitive styles such as perception, memory patterns, logical reasoning, and field dependence field independence, which directly affect the efficiency and path of second language acquisition. This article provides important theoretical support for constructing a hierarchical teaching model based on cognitive differences and implementing personalized teaching optimization, as shown in Table 1.

4) Intelligent Adaptive Learning Theory

The theory of intelligent adaptive learning relies on machine learning algorithms and models learners' behavior data, cognitive characteristics, and learning effects in real-time. It dynamically adjusts the difficulty of learning content, knowledge sequence, training methods, and feedback strategies to achieve personalized learning supply for "thousands of people, thousands of strategies". It is the underlying technical theory of intelligent technology empowering second language teaching optimization.

5) Cognitive Load Theory

The cognitive load theory points out that learners have limited working memory capacity, and teaching content and task design need to be adapted to cognitive load thresholds to avoid cognitive overload or cognitive idleness. Provide important theoretical guidance for optimizing the arrangement of second language teaching content, splitting cognitive tasks, and setting learning difficulty gradients for intelligent technology.

C. ADAPTATION LOGIC BETWEEN INTELLIGENT TECHNOLOGY AND SECOND LANGUAGE ACQUISITION COGNITION

1) Observation Adaptation: From Implicit Cognition to Explicit Quantification

Traditional second language cognition cannot be directly observed. Intelligent eye tracking and EEG technology can capture real-time physiological signals of language processing, and big data can record the trajectory of acquired behavior, transforming implicit cognitive activities into quantifiable and analyzable explicit data, achieving empirical research on cognitive mechanisms.

2) Process Adaptation: From Static Cross-Section to Dynamic Tracking

Second language acquisition cognition is a long-term dynamic evolution process, and intelligent big data can continuously collect acquisition data, track the entire process of interlanguage development and cognitive structure reconstruction, and break through the limitations of traditional static research.

TABLE 1. Classification and Core Functions of Intelligent Technology for Second Language Acquisition

Technology Category	Core Function	Application Scope
Cognitive Neuroscience Technology	Eye tracking and ERP signal detection	Cognitive process real-time observation
Natural Language Processing	Syntactic parsing and semantic mining	Rule cognition and semantic construction
AI Speech Evaluation Technology	Pronunciation correction and oral interaction	Spoken communicative output training
Learning Big Data Analytics	Learning behavior mining and cognitive clustering	Individual cognitive feature identification
Machine Learning Adaptive Technology	Personalized learning path and content recommendation	Cognitive adaptation teaching supply

3) Differential Adaptation: From Group Unity to Individual Precision

Intelligent algorithms can cluster and identify learners with different cognitive styles, memory capacities, and rule induction abilities, accurately characterizing individual cognitive differences and providing a basis for hierarchical teaching and personalized cognitive training.

4) Teaching Adaptation: From Knowledge Infusion to Cognitive Activation

Intelligent technology can optimize language input, design gradient tasks, provide real-time cognitive feedback, create communicative cognitive contexts based on cognitive processing laws, activate learners' higher-order cognitive abilities, and achieve deep adaptation between teaching and cognitive mechanisms.

III. THE COGNITIVE HIERARCHY OF SECOND LANGUAGE ACQUISITION AND THE COGNITIVE DILEMMA OF TRADITIONAL TEACHING

A. INNER COGNITIVE HIERARCHY STRUCTURE IN SECOND LANGUAGE ACQUISITION

Second language acquisition is not a single process of knowledge memorization, but a complete processing system consisting of five core cognitive dimensions. While these dimensions exhibit a foundational-toadvanced progression, rule induction and semantic construction often function as intertwined, simultaneous processes rather than a strict linear sequence, reflecting the characteristic non-linear evolution of the interlanguage system. The levels are transmitted and iterated in sequence, jointly determining the acquisition effectiveness, as shown in Table 2.

1) Perceived Attention Cognitive Hierarchy

Perceived attention is the initial cognitive stage of second language acquisition, which refers to the cognitive process in which learners receive second language input information such as speech, text, and discourse through auditory and visual means, and selectively filter effective language information and irrelevant interference information through selective attention. The core of this level determines the effectiveness of language input, and attention allocation, sensitivity to speech and intonation perception, and efficiency of text and visual processing directly affect the processing quality of all subsequent cognitive processes. It is also the most significant initial stage of cognitive differences between native and second language.

2) Memory Encoding Cognitive Hierarchy

The memory encoding hierarchy includes two sub steps: real-time processing of working memory and fixed storage of long-term memory. Learners encode, process, and integrate language information (vocabulary, sentence patterns, grammatical structures, discourse logic) filtered by perceptual attention, temporarily stored in working memory, and solidified into long-term language representations after repeated processing and acquisition training. The size of working memory capacity, encoding method, and memory strategy selection are the core cognitive factors that determine the efficiency of second language vocabulary accumulation and sentence structure internalization.

Semantic construction cognition focuses on the association and integration of lexical semantics, syntactic semantics, discourse semantics, and contextual semantics. Learners break the isolated memory of individual vocabulary, establish semantic association networks between vocabulary, sentence patterns, and contexts, and form a complete language semantic representation system. This level determines learners' language comprehension depth, reading reasoning ability, and logical expression ability in written writing.

B. INHERENT LIMITATIONS OF TRADITIONAL COGNITIVE RESEARCH ON SECOND LANGUAGE ACQUISITION

1) Lack of Cognitive Observation Methods and Inability to Empirically Demonstrate Implicit Processes

Traditional research can only rely on test scores, questionnaire self-assessment, and learners' verbal reflection to indirectly infer cognitive processes, and cannot observe the internal states of attention allocation, real-time memory processing, and syntactic parsing. Research conclusions are mostly subjective speculation and lack objective cognitive data support.

2) Neglecting Individual Cognitive Differences and Adopting the Group Average Research Paradigm

Traditional research often focuses on class and grade groups as research objects, smoothing out individual differences in learners' perceptual sensitivity, working memory capacity, rule induction ability, and cognitive style, making it difficult to explain the cognitive roots of the differentiation of acquisition effects under the same teaching conditions.

TABLE 2. Cognitive Hierarchy Structure of Second Language Acquisition

Cognitive Hierarchy	Core Connotation	Key Cognitive Characteristics
Perception and Attention	Screen and filter effective language input	Selective information processing at initial stage
Memory Encoding	Working memory processing and long-term memory consolidation	Internalization and solidification of language representation
Rule Induction	Summarize grammar and pragmatic rules from linguistic samples	Higher-order logical reasoning and pattern recognition
Semantic Construction	Build semantic network of vocabulary, syntax and discourse	Context understanding and pragmatic meaning cognition
Communicative Output	Language output, interaction feedback and cognitive revision	Interlanguage development and closed-loop iteration

3) Static Cross-Sectional Research Is the Main Focus, Lacking Dynamic Cognitive Evolution Tracking

Multiple surveys conducted in a specific semester or grade cannot track the long-term evolution trajectory of learners' second language cognitive structure and interlanguage system during their university years, making it difficult to reveal the non-linear developmental patterns of acquisition.

4) Cognitive Influencing Factors Are Difficult to Quantify, and the Correlation Mechanism Is Vague

The correlation between mother tongue transfer, teaching mode, learning strategies, emotional factors, and cognitive processing efficiency is mostly qualitatively described, and it is difficult to quantify the impact weights of each factor on the five cognitive levels, making it difficult to accurately attribute acquisition barriers.

C. THE COGNITIVE MISMATCH DILEMMA IN TRADITIONAL SECOND LANGUAGE CLASSROOM TEACHING

1) Mismatch Between Teaching Supply and Perceived Cognition

The input form of teaching language is single, mainly consisting of textbook text and oral teaching by teachers, lacking multimodal voice, image, and situational input, which cannot adapt to the visual and auditory perceptual cognitive preferences of different learners; Unreasonable classroom information density can easily lead to cognitive overload for some learners and cognitive idleness for others.

2) Teaching Rhythm and Cognitive Mismatch in Memory

The unified teaching schedule ignores the differences in learners' working memory capacity. Learners with fast memory speed cannot receive expansion training, and learners with slow memory speed cannot keep up with the teaching pace; Lack of gradient review arrangement based on forgetting rules makes it difficult to solidify knowledge encoding into long-term memory, resulting in severe fragmented forgetting. To verify the effectiveness of the proposed model, a 16-week pedagogical experiment was conducted involving 120 undergraduate students (60 in the Experimental Class, 60 in the Control Class). The Experimental Class utilized the 'SmartL2' adaptive learning platform and Eye-Link 1000 Plus for real-time tracking. Table 3 shows the preexperiment cognitive ability comparison between the two classes.

3) Knowledge Infusion and Rule Induction Cognitive Mismatch

The classroom mainly focuses on teachers directly teaching grammar rules, depriving learners of the cognitive processes of independent observation, sample induction, and logical deduction, resulting in passive memorization of rules by learners, inability to flexibly transfer and apply them, and weak construction of the interlanguage system.

4) Shallow Explanation and Semantic Construction Cognitive Mismatch

Teaching often focuses on the literal meaning of vocabulary and surface translation of sentence structures, lacking in-depth explanation of semantic associations, contextual logic, and pragmatic connotations. Learners find it difficult to establish a systematic semantic network, and their reading comprehension and writing expression remain at a shallow level.

5) Mechanical Practice and Cognitive Mismatch in Communicative Output

After class, the focus is mainly on mechanical exercises such as multiple-choice questions and fill in the blank questions. There is a lack of real-life oral communication and open-ended writing output tasks, as well as a lack of meaningful negotiation and feedback correction, which cannot force cognitive level rule optimization and semantic reconstruction. The development of higher-order communicative cognitive abilities lags behind.

IV. THE TECHNICAL DIMENSION AND MECHANISM OF INTELLIGENT TECHNOLOGY EMPOWERING THE COGNITIVE MECHANISM OF SECOND LANGUAGE ACQUISITION

A. CORE INTELLIGENT TECHNOLOGY CLUSTER EMPOWERING SECOND LANGUAGE ACQUISITION COGNITION

1) Cognitive Neural Observation Techniques

With eye tracking technology, ERP event-related potentials, and fMRI functional magnetic resonance imaging as the core, it can collect real-time eye movement trajectories, gaze duration, and brain activation signals during learners' reading, vocabulary processing, and syntactic comprehension processes, accurately reflecting the real-time cognitive state of perceptual attention and semantic parsing, and pro-

TABLE 3. Pre-experiment Cognitive Ability Comparison Between Two Classes

Cognitive Dimension	Experimental Class	Control Class	Significance Difference
Perception and Attention	71.36	70.92	Insignificant
Memory Encoding	69.58	70.25	Insignificant
Rule Induction	68.74	69.16	Insignificant
Semantic Construction	70.15	69.83	Insignificant
Communicative Output	67.93	68.47	Insignificant

viding physiological empirical data for cognitive mechanism research.

2) Natural Language Processing Technology

Covering vocabulary segmentation, syntactic parsing, semantic mining, intelligent grammar correction, text similarity calculation, and discourse logic analysis, it can automatically decompose the structure of the second language, analyze rule errors and semantic deviations in learners' writing and oral output, and accurately locate acquisition barriers at the level of rule cognition and semantic construction.

3) AI Voice Evaluation and Human-Computer Interaction Technology

By relying on speech recognition, intonation and rhythm analysis, oral pronunciation correction, and intelligent dialogue practice functions, real-time capture of learners' pronunciation errors, intonation and rhythm, and sentence structure application problems in oral output, create immersive communication situations, activate cognitive levels of communication output, and provide instant interactive feedback.

B. THE ROLE PATH OF INTELLIGENT TECHNOLOGY INTERVENTION IN THE FIVE COGNITIVE LEVELS OF SECOND LANGUAGE ACQUISITION

Intelligent technology enriches language perception channels through multimodal inputs (audio, video, situational animation, bilingual text) and adapts to different learners' perceptual preferences; Based on big data analysis of learners' attention periods, intelligently optimize classroom teaching pace and information presentation methods; By analyzing eye movement data to focus on hotspots, identify blind spots and weak points in learners' language information perception, and accurately optimize input presentation forms, as shown in Table 4.

The intelligent platform provides a large number of hierarchical language samples, guiding learners to independently compare and observe sentence structure differences. Through machine learning clustering, it presents rule distribution patterns and assists learners in autonomously summarizing grammar and pragmatic rules; The intelligent error classification system categorizes similar rule errors, helps learners extract error patterns, correct cognitive biases, and improve the interlanguage rule system.

Natural language processing technology constructs a vocabulary semantic association network and a contextual

semantic scene library, intelligently pushing synonyms, collocation associations, and contextual examples to help learners establish systematic semantic associations; Through intelligent analysis of discourse logic, guide learners to organize semantic logic between sentences and paragraphs, and enhance their cognitive abilities in discourse semantic construction and logical deduction.

C. THE OVERALL MECHANISM OF INTELLIGENT TECHNOLOGY EMPOWERING SECOND LANGUAGE COGNITIVE MECHANISMS

Intelligent technology takes data collection, cognitive observation, feature modeling, differential clustering, adaptive intervention, and cognitive iteration as its core logic. It observes implicit cognitive processes at the physiological level, explores cognitive patterns at the behavioral level, characterizes individual cognitive differences at the algorithmic level, and implements cognitive adaptive intervention at the teaching level. It comprehensively intervenes in the five cognitive levels of second language acquisition perception, memory, rules, semantics, and communication, promoting the upgrading of the research paradigm of second language acquisition cognition and providing underlying cognitive basis for optimizing classroom teaching.

V. DECONSTRUCTION OF DEEP COGNITIVE MECHANISMS IN SECOND LANGUAGE ACQUISITION EMPOWERED BY INTELLIGENT TECHNOLOGY

A. EVOLUTION OF PERCEPTION ATTENTION COGNITIVE MECHANISMS UNDER INTELLIGENT TECHNOLOGY

Intelligent multimodal language input changes the traditional single text input mode, with parallel stimulation of visual, auditory, and situational multi-channel information. Learners' attention allocation shifts from single text gaze to multi-dimensional information collaborative processing; Empirical evidence from eye tracking data shows that contextualized contexts can significantly enhance learners' fixation duration and attention concentration on core vocabulary and key sentence patterns, reduce irrelevant information interference, and improve language input efficiency.

Intelligent classrooms can actively guide learners to focus on core language knowledge points through dynamic information pop ups, key annotations, and voice highlighting, compensating for learners' lack of independent attention screening ability and improving the quality of second language acquisition and processing starting points from the

TABLE 4. Post-experiment Evaluation Results of Cognitive and Learning Effect

Evaluation Index	Experimental Class	Control Class	Score Promotion
Final Written Exam	82.65	75.38	7.27
Oral Communication Ability	80.42	73.15	7.27
Perception and Attention Ability	79.53	72.46	7.07
Memory Encoding Ability	78.96	71.85	7.11
Rule Induction Ability	77.84	70.62	7.22
Semantic Construction Ability	81.25	74.39	6.86

cognitive source.

B. EVOLUTION OF MEMORY ENCODING COGNITIVE MECHANISMS UNDER INTELLIGENT TECHNOLOGY

1) Personalized Forgetting Curve and Memory Encoding Solidification Law

Intelligent big data tracks the vocabulary and sentence pattern forgetting trajectory of each learner, generates personalized forgetting curves, and breaks the unified review mode; The adaptive system accurately matches review nodes, achieves precise reinforcement coding, and greatly improves the efficiency of converting working memory into long-term language representations.

2) Memory Processing Patterns Under Dynamic Regulation of Cognitive Load

Machine learning dynamically evaluates cognitive load based on learners' real-time answer accuracy and learning duration, intelligently splits complex grammar and long sentence knowledge units, increases learning difficulty in gradients, and always maintains cognitive load within a reasonable threshold to avoid coding failure and memory fragmentation caused by overload.

C. EVOLUTION OF RULE INDUCTION COGNITIVE MECHANISM UNDER INTELLIGENT TECHNOLOGY

1) Autonomous Rule Induction Mechanism Driven by Sample Clustering

Intelligent technology gathers massive hierarchical language samples and presents the distribution patterns of sentence structures and grammatical collocations through algorithm clustering, guiding learners to independently extract abstract rules from specific samples, replacing traditional teachers' direct indoctrination, activating higher-order cognition of inductive reasoning, and achieving deep internalization and flexible transfer of rules.

2) Rule Bias Intelligent Attribution and Cognitive Correction Mechanism

Natural language processing automatically identifies the types of grammar errors made by learners, distinguishing whether they are cognitive biases caused by mother tongue transfer, incomplete rule induction, or contextual pragmatic cognitive deficiencies. It accurately attributes the cognitive roots, pushes similar variant training, and achieves the reconstruction of deep cognitive rules from surface level error correction.

VI. RESEARCH CONCLUSION

Firstly, second language acquisition is a five level progressive cognitive hierarchy system consisting of perceptual attention, memory encoding, rule induction, semantic construction, and communicative output. Each level is interrelated and iteratively iterated, serving as the intrinsic core of interlanguage development and language proficiency enhancement; Traditional second language cognitive research has limitations such as a lack of observational methods, neglect of individual differences, and a focus on static research. Traditional classroom teaching also faces the problem of a comprehensive mismatch between teaching supply and the five cognitive levels.

Secondly, intelligent technologies that empower second language acquisition cognition can be divided into five clusters: cognitive neural observation, natural language processing, AI speech interaction, big data learning analysis, and machine learning adaptation. Each technology precisely intervenes in each cognitive level of second language acquisition from different paths, forming a clear mechanism of technological empowerment. Thirdly, intelligent technology has reshaped the deep cognitive mechanisms at various levels of second language acquisition, changing the internal operating rules of learners' attention allocation, memory encoding, rule induction, semantic construction, and communicative output, achieving observable cognitive processes, quantifiable cognitive differences, and traceable cognitive development.

Fourthly, the five link intelligent teaching model constructed based on cognitive mechanisms proposes an optimization path from five dimensions: teaching objectives, teaching content, teaching mode, classroom interaction, and evaluation system. Through empirical testing in the classroom, it can significantly improve the effectiveness of second language acquisition and learners' cognitive abilities, and has replicable and promotable practical value.

AUTHOR CONTRIBUTIONS

Hongyi He designed, collected and analyzed the data, and drafted the manuscript. Hongyi He conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Hongyi He participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity

of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

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REFERENCES

- [1] Z. S. Alavi, B. F. Bryant, E. M. Shirvan, et al., "Exploring Savoring Experiences, Strategies, and Barriers in L2 Learning: Insights from a Qualitative Study with EFL Learners," *International Journal of Applied Positive Psychology*, vol. 11, no. 2, pp. 19-19, 2026, doi: 10.1007/s41042-026-00279-9.
- [2] P. Wang, L. Ganushchak, C. Welie, et al., "Emotions Are Not Random: Machine Learning Reveals Predictable Patterns in a 21-Day Second Language Learning Trajectory," *Educational Psychology Review*, vol. 38, no. 1, pp. 49-49, 2026, doi: 10.1007/s10648-026-10141-8.
- [3] H. Yu, J. C. McMahon, E. S. Köhler, et al., "Twelve tips for teaching medical communication skills in a second language," *BMC medical education*, 2026, doi: 10.1186/s12909-026-09130-w.
- [4] A. F. Alkohilani and M. N. Alshehri, "Language anxiety in learning Arabic as a second Language: A Case Study of Female Learners at the Arabic Language Institute for Speakers of Other Languages in King Abdulaziz University," *International Journal of Linguistics, Literature and Translation*, vol. 9, no. 4, pp. 13-22, 2026, doi: 10.32996/ijllt.2026.9.4.2.
- [5] Y. Jiang and C. Lau, "Parental Involvement and Children's Second Language Learning: A Mixed-Methods Study," *Early Education and Development*, vol. 37, no. 3, pp. 622-643, 2026, doi: 10.1080/10409289.2025.2582182.
- [6] B. C. Lam and H. K. K. Chung, "Metalinguistic Skills Were Uniquely Linked to Chinese Word Reading and Writing Among First and Second Language Learners," *Early Education and Development*, vol. 37, no. 3, pp. 566-580, 2026, doi: 10.1080/10409289.2025.2577954.
- [7] X. Geng, "Dynamic Assessment in Second Language Learning: Theoretical Foundations and Practical Applications," *International Education Forum*, vol. 4, no. 2, pp. 23-27, 2026, doi: 10.26689/ief.v4i2.14027.
- [8] T. V. Laughlin, J. Dombi, T. Sydorenko, et al., "L2 learners' pragmatic output in a face-to-face vs. a computer-guided role-play task: Implications for TBLT," *Language Teaching Research*, vol. 30, no. 3, pp. 1593-1618, 2026, doi: 10.1177/13621688231188310.
- [9] A. Vraciu and A. Marsol, "Content-specific vocabulary in CLIL: Exploring L2 learning outcomes in a primary education programme in Catalonia," *Language Teaching Research*, vol. 30, no. 3, pp. 1082-1100, 2026, doi: 10.1177/13621688231170073.
- [10] W. Zhao, "Profiling Chinese character acquisition by CSL learners: A cognitive diagnostic analysis," *Journal of Chinese Writing Systems*, vol. 10, no. 1, pp. 1-17, 2026, doi: 10.1177/25138502261424507.
- [11] L. Jingyuan, "A Critical, Synthesis-oriented Literature Review Related to L2 Learner Emotions in the Area of Second Language Acquisition," *Global vision research*, pp. 3(1), 2026, doi: 10.69979/3041-0843.26.01.063.
- [12] C. Caitlin and R. R. Alan, "Disability and second language learning: Implications for interdisciplinary research in applied linguistics," *Studies in Second Language Acquisition*, vol. 48, no. 1, pp. 4-18, 2026, doi: 10.1017/s0272263126101594.
- [13] K. Raman, W. W. Lun, and H. Hashim, "Virtual reality for verbal communication development in English as second language learning: Advantages and optimisation strategies," *Computers & Education: X Reality*, vol. 8, p. 100145, 2026, doi: 10.1016/j.cexr.2026.100145.
- [14] M. P. Bautista, "Multidimensional Analysis of Senior High School Student Engagement in English as a Second Language: Interplay of Affective, Cognitive, and Behavioral Factors," *Journal of English Language Teaching and Applied Linguistics*, vol. 8, no. 3, pp. 19-32, 2026, doi: 10.32996/jeltal.2026.8.3.3.
- [15] T. L. L. Diem and D. T. Minh, "A Cross-Sectional Dataset for the Validation of an L2 Student Engagement Scale: Evidence from a Vietnamese Context," *Journal of Open Humanities Data*, vol. 12, pp. 29, 2026, doi: 10.5334/johd.446.
- [16] E. Tsigeman, M. Likhanov, L. Kalinnikova, et al., "Why Dysfluent Font Does Not Aid Second Language Learning," *The Journal of Experimental Education*, vol. 94, no. 2, pp. 255-269, 2026, doi: 10.1080/00220973.2024.2446189.
- [17] L. Portolés, A. S. Gila, M. Schauer, M. Economidou-Kogetsidis, M. Savić, and A. Myrset, "Second Language Pragmatics and Young Language Learners: EFL Primary School Contexts in Europe," *Journal of Pragmatics*, vol. 254, pp. 91-93, 2026, doi: 10.1016/j.pragma.2026.01.002.
- [18] W. Yanjun, W. Jianqin, and M. Brian, "Chunking words into multi-word expressions: exploring chunking ability in immediate recall among second language learners of Chinese," *Applied Psycholinguistics*, vol. 47, pp. e1, 2026, doi: 10.1017/s0142716425100441.
- [19] D. Wang and H. Wang, "Exploring the effects of the noticing function of output on second language learning in a four-stage Chinese-English translation task," *Asian-Pacific Journal of Second and Foreign Language Education*, vol. 11, no. 1, pp. 7, 2026, doi: 10.1186/s40862-025-00372-7.
- [20] S. Fang and X. Liu, "Predictive processing in L2 learners: contributions of cognitive and affective factors," *Psychological research*, vol. 90, no. 1, pp. 17, 2026, doi: 10.1007/s00426-026-02235-3.