

A visual analysis of the current status and trends of research on Mandarin tone acquisition by non-native Chinese speakers based on citespace

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Abstract:

This study employs CiteSpace to provide a visual analysis of the current state and trends in research on Mandarin tone acquisition by non-native speakers. Through data analysis of 131 papers from the Social Sciences Citation Index (SSCI) and Scopus databases between 2015 and 2024, the Spatio-temporal distribution patterns, collaboration networks among authors/institutions, and keyword-based topic clusters were examined. The primary findings indicate a peak in publication volume from 2019 to 2021, with the United States and China as the major contributors. However, the collaborative network in this field is fragmented, with limited core authors and insufficient international collaboration. Keyword co-occurrence and burst detection highlight five major research areas: (1) perceptual mechanisms and acoustic features of Mandarin tone learning; (2) acquisition trajectories and proficiency effects; (3) teaching strategies and training methods; (4) cognitive and neural processing; and (5) cross-linguistic and cultural influences. Notably, perceptual training, auditory stimuli, and second language perception are identified as emerging hotspots. This study emphasizes the significance of bolstering interdisciplinary collaboration, a more profound focus on teaching approaches to tonal instruction, and the integration of technological innovations. The research provides a comprehensive foundation for the study and practice of Mandarin tone teaching for non-native learners.

Keywords: CiteSpace visualization, Mandarin tone, L2 learners, Quantitative research

1. Introduction

Mandarin, one of the most widely spoken languages globally, has seen a surge in non-native speakers learning it in recent years. However, learning Mandarin presents a challenge for non-Chinese speakers, mainly due to its intonation. Learners often face perceptual and cognitive challenges in identifying and pronouncing correct tones in Chinese, resulting in frequent miscommunication and misunderstanding. Consequently, research on Mandarin tone acquisition has become a critical area within second language acquisition, particularly in the field of Teaching Chinese as a Second Language (TCSL; hereafter TCSL). In recent years, research on Mandarin tone acquisition by non-native speakers has significantly advanced, driven by developments in language teaching theory and modern technology. The scope of researches has gradually expanded from initial stage tone discrimination and perception studies to various aspects, including tone perception training, individual learner differences, and high-tech-assisted teaching.

To analyze the current state, key topics, and trends in TCSL research on Mandarin tones, this paper utilizes CiteSpace visualization software to conduct an in-depth analysis of journal articles from the Web of Science (SSCI) and Scopus databases, spanning from January 1, 2015, to December 31, 2024, focusing on Mandarin tone teaching for non-native speakers. The analysis aims to map the knowledge map in the field, enrich the existing research results, and provide recommendations for future Chinese as a second language practice.

1.1 Research Method

This study adopts an information visualization approach to systematically investigate the research landscape of Mandarin tone acquisition by non-native speakers. As the primary analytical tool, CiteSpace—a Java-based scientific knowledge mapping software developed by Professor Chaomei Chen—is employed to conduct bibliometric analysis on relevant domestic and international literature. Recognized for its effectiveness in visualizing research trends and intellectual structures, CiteSpace enables quantitative examination of domain-specific literature through multiple dimensions, including collaborative networks, research frontiers, and thematic evolution. Specifically, it identifies key contributors (authors/institutions), geographical distributions, and conceptual hotspots through co-occurrence and cluster analysis of bibliographic data.

For data processing and visualization, the following parameters were configured in CiteSpace: 1) Temporal scope spanning 2015 to 2024 with annual time slices to capture evolutionary patterns; 2) Node types comprising authors,

institutions, countries/regions, and keywords to map research collaboration networks and conceptual frameworks. The generated visualizations are complemented by quantitative validations through Excel-based data plots, ensuring triangulation of findings through both graphical representations and statistical outputs. This dual-layer analytical strategy facilitates a comprehensive understanding of current research status, disciplinary collaborations, and emerging directions in Mandarin tone acquisition studies.

1.2 Research Question

This paper primarily addresses the following inquiries: What are the overall research advancements in Mandarin tone teaching for L2 learners from 2015 to 2024? What are the spatiotemporal distribution characteristics of the research literature? Who are the authors, and which countries and research institutions are involved?

2. The overall research progress of tone teaching for L2 speakers of Mandarin

2.1 Data sources

This study collected bibliometric data from two authoritative databases: Web of Science Core Collection's Social Sciences Citation Index (SSCI) and Scopus. Initial queries employed Boolean operators with the search terms "mandarin AND tone" combined with "acquiring OR acquisition OR learn OR learning", generating preliminary results across multiple disciplines. To refine the dataset, exclusion criteria were systematically applied by removing articles containing the terms "cochlear implants", "gesture", or "sing", which were unrelated to linguistic tone acquisition. This refinement yielded 280 articles from Web of Science and 267 from Scopus.

Subsequent manual screening eliminated studies with low thematic alignment to non-native Mandarin tone acquisition, followed by automated duplicate removal using CiteSpace's built-in algorithm. The final curated dataset included 42 core articles from Web of Science and 89 articles from Scopus, yielding a final corpus of 131 high-relevance publications.

2.2 Distribution Characteristics of Research Literature Time Periods

The evolution of this research domain can be systematically analyzed through temporal patterns in scholarly output, as showed by annual publication trends presented in Figure 1. The longitudinal data reveals steady growth in research activity between 2015 and 2019, followed by a period of relative stability and peak productivity from

2019 to 2021. While a gradual decline was observed from 2021 to 2023, publication volumes consistently maintained levels above those recorded in 2016. Notably, the dataset indicates resurgence in research output commencing in 2024. Within the corpus of 131 analyzed publications, 42 articles (representing approximately 32% of total output) originated from SSCI sources.

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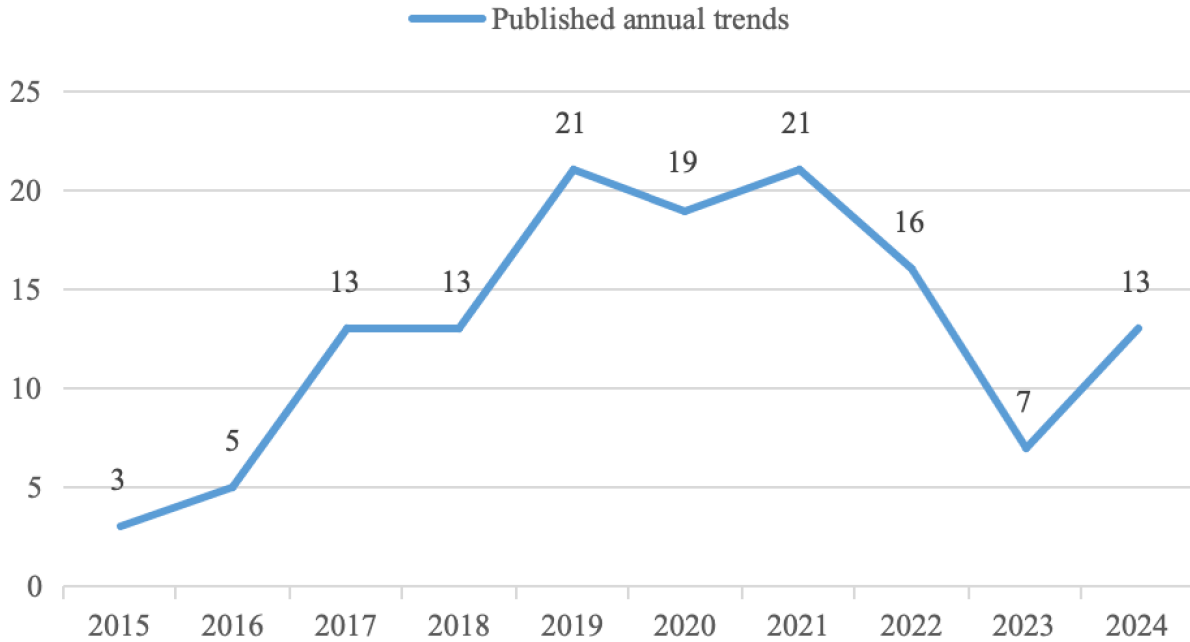


Figure 1 Changes in the Number of Published Documents from 2015-2024

2.3 Spatial Distribution Characteristics of Research Literature

2.3.1 Distribution Status of Authors

Examining the research authors within this field can help one understand the research level. The general characteristic is that the research authors are numerous and dispersed. From the perspective of publication volume, the author with the most publications is Tsukada Kimiko, with 8 articles. Referring to Price's Law, the minimum number of articles that core authors in this field should publish can be calculated.

Based on Price's Law, the core authors are defined as those who have published at least m_p articles. The formula for this calculation is as follows:

$$m_p = 0.749 \sqrt{n_{pmax}} \quad (\text{Meng \& Ding, 1998})$$

The variable ' m_p ' denotes the number of publications required for a researcher to be considered a core author. The variable ' n_{pmax} ' represents the number of publications by the author with the highest publication count. Consequently, The calculated m_p value for this research domain is 5.992. This indicates that an author must publish a minimum of six articles to be considered a core contributor within this field. Statistical analysis reveals that only one

individual has published eight articles, one has published four articles, twelve have published three articles, and thirty-six have published two articles. These findings suggest a scarcity of highly productive authors and a corresponding lack of established core researchers. Consequently, this domain presents significant opportunities for further researches.

Subsequently, author network examination was performed using CiteSpace's analytical framework. The co-occurrence network visualization (Figure 2) contains 200 discrete nodes connected through 232 links, yielding a network density of 0.0117. This structural configuration shows established yet limited collaborative patterns within the research community, with the low density value suggesting predominantly decentralized scholarly interactions. A substantial presence of unconnected nodes implies prevalent independent research practices or narrowly focused partnerships. These patterns suggest that research efforts are primarily driven by individual researchers or small teams rather than large collaborative groups, with limited evidence of extensive knowledge sharing or resource integration across the research community. The observed network characteristics emphasize the need for enhanced interdisciplinary cooperation and systematic consolidation of research expertise in future studies.

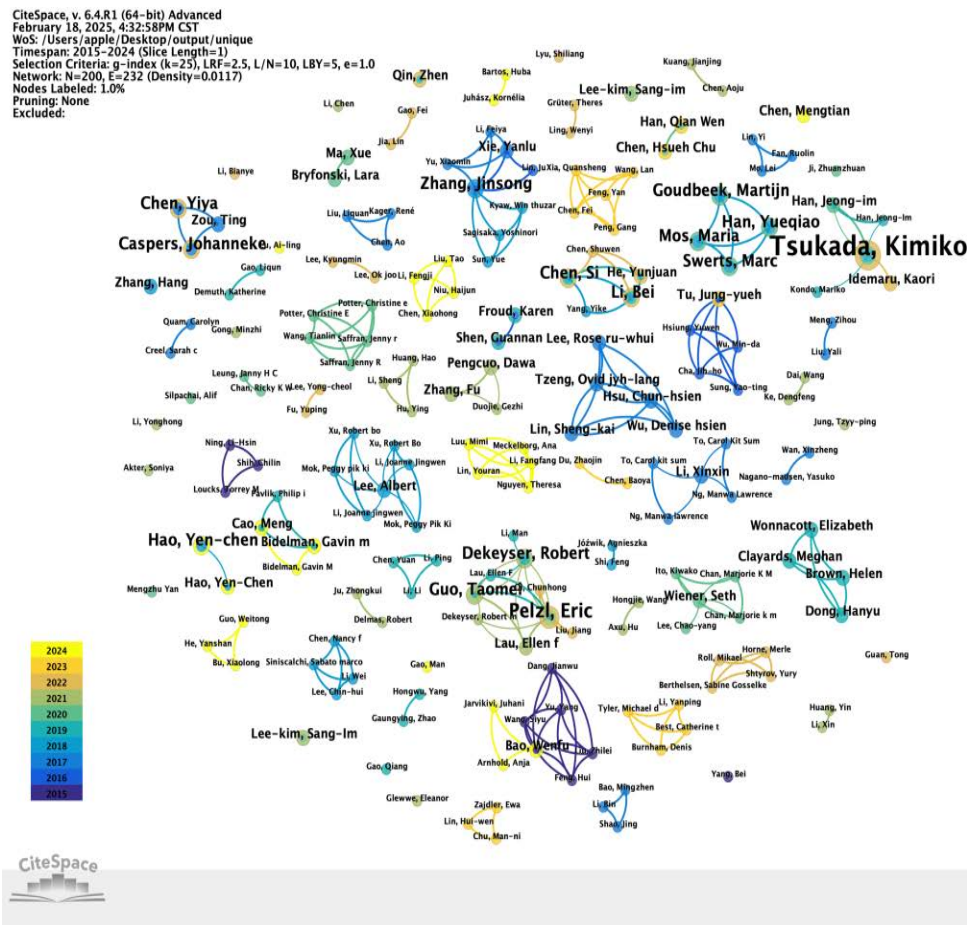


Figure 2 Map of Author Co-occurrence Network

2.3.2 Distribution Status of Countries

The spatiotemporal analysis of research contributions in popular science journals, as depicted in Figure 3, identifies leading contributors through geographic visualization. Network node examination reveals the United States and China as principal contributors, with node dimensions proportionally representing regional research output volumes. The disproportionately large node dimensions for these two nations confirm their research leadership and

sustained longitudinal contributions. Both countries maintain robust independent research programs while simultaneously engaging in multilateral collaborations. However, the dataset's limited geographic scope - comprising only 18 countries/regions across 131 publications - indicates constrained participation diversity and underdeveloped international cooperation networks. This spatial concentration suggests substantial potential for expanding multinational research initiatives.

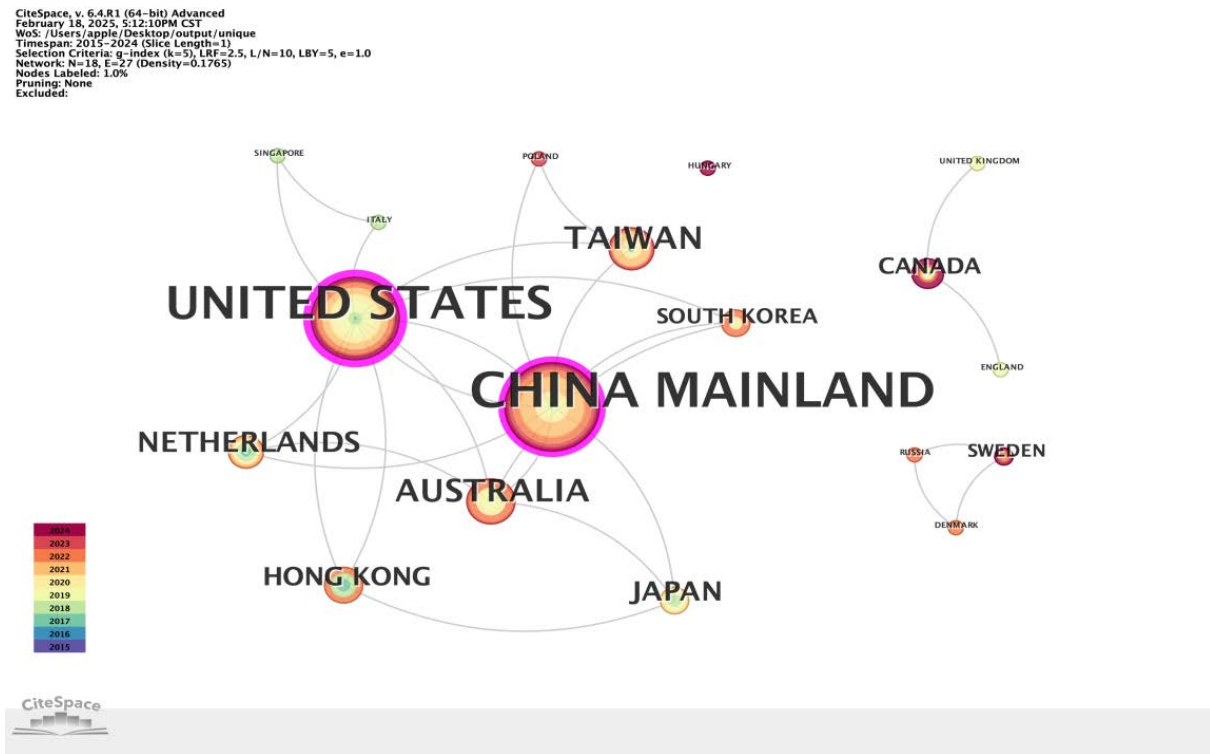


Figure 3 Map of Country Cooperation Network

2.3.3 Distribution Status of institutions

The institutional analysis of popular science journal research, visualized in Figure 4, identifies prominent contributors through network node representation. Beijing Language and Culture University, Hong Kong Polytechnic University, and Chinese University of Hong Kong emerge as central nodes demonstrating notable research influence. The visualization documents established collaborative partnerships between these institutions and international

counterparts including Columbia University, Pennsylvania State University, and University of Melbourne. Network parameters (148 nodes, 196 links, density=0.018) reveal restricted direct connectivity between institutional entities, with collaborative interactions primarily occurring through intermediary hub institutions. This structural configuration indicates underdeveloped direct institutional linkages and highlights opportunities for optimizing collaborative networks through strengthened inter-institutional engagement.

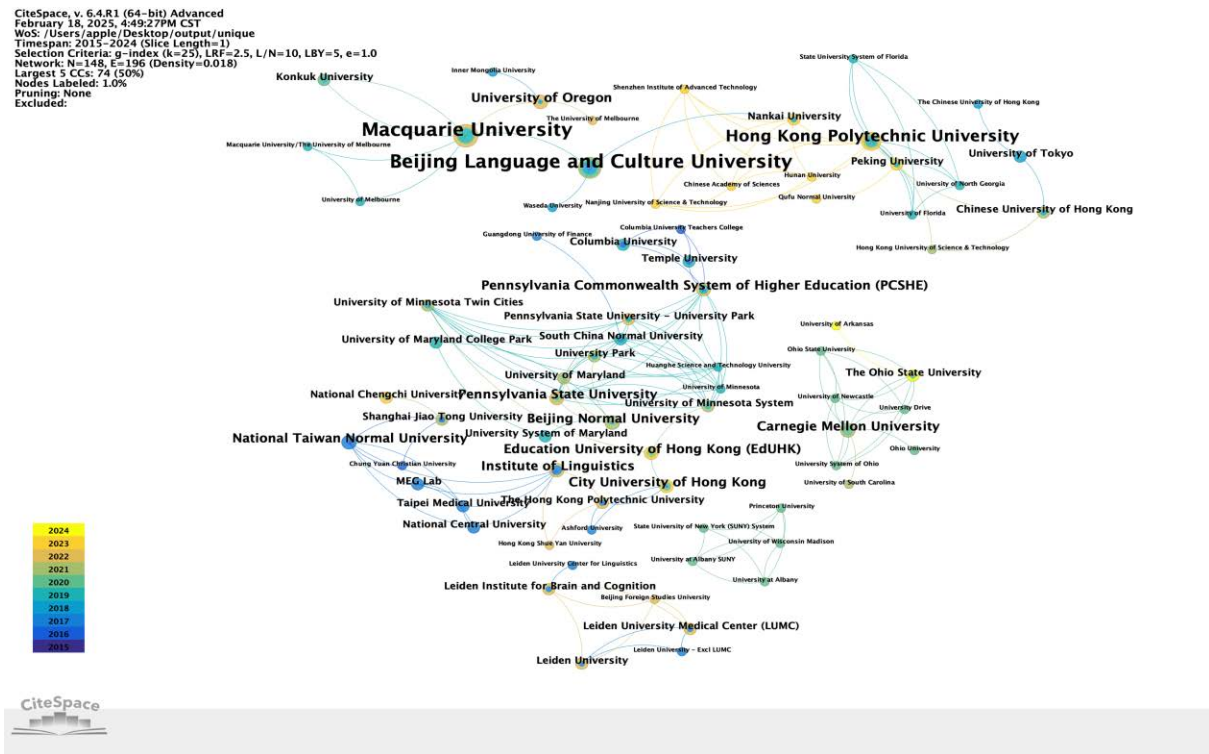


Figure 4 Map of Institutional Cooperation Network

2.3.4 Keyword Co-occurrence Map Analysis

Keywords serve as a concise summary of a document's central themes. Analyzing the keywords within a body of literature allows for the identification of research hotspots, emerging trends, and the relationships between various research topics. A bibliometric analysis was conducted on 131 documents using CiteSpace, resulting in a network comprising 241 nodes and 854 edges, with a network density of 0.0295. A modularity (Q) value exceeding 0.3 indicates a significant network community structure, with values approaching 1 signifying enhanced network clustering (Li et al., 2022, p.105, 137). The modularity, $Q = 0.6628$, indicates a robust community structure within the network.

The co-occurrence map of keywords in this research area from 2015 to 2024 is presented in Figure 5. In Figure 5, nodes are represented as "Tree Ring History." The size

of the tree ring reflects the frequency of keyword occurrences, with larger rings indicating higher frequency. The color of the tree ring represents the active time period of the keyword, with color changes from the inside to the outside indicating the publication time zone from early to present. The thickness of the tree ring is proportional to the frequency of keyword occurrences within the corresponding time partition (Li et al., 2022, p.105, 137). As shown in Figure 5, there are 10 high-frequency keywords with a count ≥ 10 in this research area, namely "english", "speech perception", "perception", "mandarin", "mandarin chinese", "human", "article", "adult", "language", and "listeners". There are 13 core keywords with a centrality ≥ 0.1 in this research area, including "categorical perception", "mandarin tones", "english", "speech perception", "acquisition", "chinese tones", "speech", "acoustic features", "acoustics", "cantonese", "discrimination", "lexical tones", and "mandarin chinese".

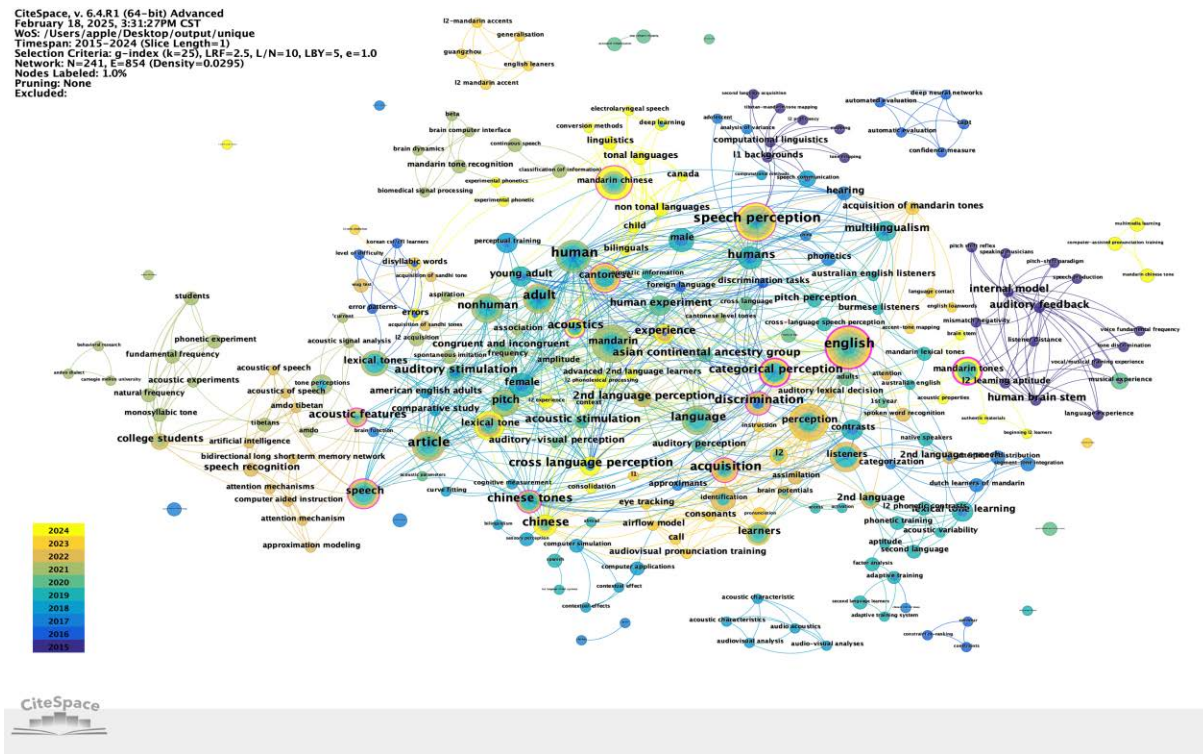


Figure 5 Map of Keyword Co-occurrence

2.3.5 Keyword Clustering Map Analysis

Keywords clustering analysis conducted through CiteSpace identified thematically similar terms within Mandarin L2 tone instruction research, with results visualized in Figure 6. The algorithmic grouping produced nine discrete clusters : #0 adult, #1 discrimination, #2 Canada, #3 phonetic experiment, #4 verbal protocols, #5 lexical tone learning, #6 Mandarin tones, #7 L2 proficiency, and #8 electroencephalography. To further synthesize research hotspots, clusters with similar keywords were merged, and, in conjunction with high-frequency research topics and centrality keywords, the primary research areas within the field were identified.

The first area is the perceptual and learning mechanisms of Mandarin tones, with key labels including #3 phonetic experiment, #5 lexical tone learning, and #6 mandarin tones. This domain primarily researches the perception and learning processes of Mandarin tones, focusing on acoustic features such as pitch, duration, and intensity, as well as the cognitive processes involved in learners' perception of these features. Key keywords in this research area include: Mandarin tones, Tone perception, Acoustic features, Fundamental frequency(Meng et al., 2024), Perceptual training(Yue, 2018), and Contextual effect(Yen-Chen, 2018).

Secondly, the acquisition of Mandarin tones, among the main keywords for this topic are #7 L2 proficiency and #5

lexical tone learning. This research field mainly focuses on studying the acquisition of Mandarin tones by learners at various learning stages, with a particular emphasis on the acquisition outcomes of learners. The main keywords of this research field include: L2 proficiency(Wenfu, 2015), L1 backgrounds, lexical tone learning, segment-tone integration, attention redistribution(Ting et al., 2017), and foreign learners of Mandarin.

Thirdly, methods and strategies for Mandarin tone teaching are examined, with key search terms including: #1 discrimination, #5 lexical tone learning, and #7 L2 proficiency. This area of research focuses on methodologies and strategies for Mandarin tone teaching, with a specific emphasis on effective instruction and learning of Mandarin tones. Primary keywords within this research field embrace: Phonetic training(Hanyu, 2019), Categorical perception(Guannan & Karen, 2019), Audiovisual pronunciation training, Talking head(Fei, 2022), Mismatch negativity (MMN)(Keke et al., 2019), and Psycho-acoustic perception(Liquan, 2017).

Fourthly, The cognitive process and neural mechanisms underlying the learning of Mandarin tones, with keyword including #4 verbal protocols, #8 electroencephalography, and #5 lexical tone learning. The main research focus in this field is on the cognitive processes and neural mechanisms learners' acquisition of Mandarin tones, with a specific emphasis on the brain's role in tonal language learning. The main keywords in this field include: Electro-

encephalography (EEG)(Shiau-Ru, 2021), Neuroplasticity(Rose, 2017), ERP (Event-Related Potential)(Eric et al., 2021), Pitch tracking(Hao, 2021), and Magnetic mismatch field (MMNm)(Rose et al., 2017).

Fifthly, the influence of cross-cultural and linguistic backgrounds, with primary keyword including #0 adult, #2 Canada, and #5 lexical tone learning. This field primarily researches the impact of diverse cultural and linguistic

backgrounds on Mandarin tone acquisition, with a specific focus on the effects of native language background and cultural differences on learning outcomes. Key research areas within this domain embrace: CSL/CFL learners(-Feiya, 2016; Rose, 2017), tonal production, Mandarin disyllabic words(Jung-Yueh, 2016), Foreign learners, cross-linguistic perception(Liquan, 2017), and Japanese L2 learners(Yue, 2018).

CiteSpace, v. 6.4.R1 (64-bit) Advanced
February 18, 2025, 3:20:50PM CST
WoS: /Users/apple/Desktop/output/unique
Timespan: 2015-2024 (Slice Length=1)
Selection Criteria: g-index (k=5), LRF=2.5, L/N=10, LBY=5, e=1.0
Network: N=241, E=854 (Density=0.0295)
Nodes Labeled: 1.0%
Pruning: None
Modularity Q=0.6628
Weighted Mean Silhouette S=0.9027
Harmonic Mean(Q, S)=0.7644
Excluded:

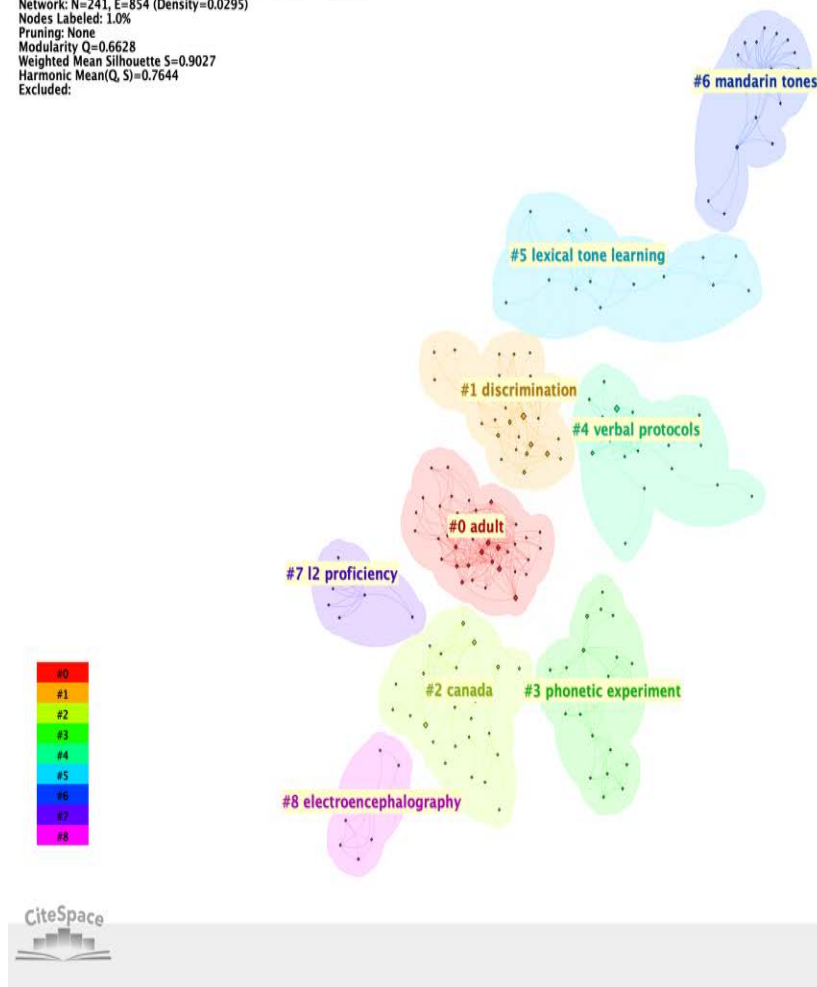


Figure 6 Map of Keywords Clustering

2.3.6 Keyword Emergence Map Analysis

The analysis of the top 24 keywords with the most citations and their temporal evolution (from 2015 to 2024) as shown in Figure 7 reveals the changes in research focus. Early foundational keywords (“discrimination,” “humans”) first appeared in 2016, establishing initial research frameworks. In the following years, new research focuses emerged: “perceptual training” (in 2017) and “auditory stimulation” (in 2018) showed increasing academic atten-

tion. The keyword “non-human” (artificial intelligence/computer language application) maintained a consistently significant position from 2018 to 2021, while “speech” research remained an active field from 2018 to 2020. In 2018, a significant phenomenon of keyword concentration emerged, and four keywords stood out prominently: Cantonese, “non-human”, “speech”, and “intonation”. This marked the year as a crucial stage for concept expansion. Citation burst analysis identified five keywords with the strongest influence: perceptual training (1.95), lan-

guage (1.68), learner (1.5), human experiment (1.46), and speech (1.09). These keywords reflect their core positions in the development of the field.

Recent trends indicate that the popularity of the two concepts, “Second Language Perception” (in 2020) and “Perception” (in 2022), has risen rapidly within a short period

of time. This suggests that researchers’ attention to the perception mechanism during language acquisition has significantly increased. This temporal distribution highlights the transformation of the core research topic and reflects the changes in current research trends, providing new ideas for future research.



Figure 7 Keywords with the Strongest Citation Bursts

3. Analysis of the Current Research Status from the Keyword Emergence

The analysis of the co-occurrence patterns of keywords in the journals indexed by SSCI (Social Sciences Citation Index) reveals the concentrated research themes in this field, including language perception, teaching methods, and auditory and visual stimulus research(Yueqiao), etc. Keywords such as “perception training”, “auditory stimulus”, and “speech” stand out with continuous citation peaks, reflecting that researchers are willing to conduct combined research in the two fields of linguistics and cognitive psychology. Meanwhile, non-SSCI academic literature shows the characteristics of lexical diversity and diverse research fields, such as “language experience” and “cross-language perception”, indicating significant progress in interdisciplinary research. From the perspective of the fields involved in the keyword emergence, these keyword emergences indicate that SSCI journals tend to publish experimental and methodologically rigorous academic papers. While the keyword emergences of the entire research field cover a wider range of fields, including linguistics, psychology, and education, etc. Therefore, it can be concluded that SSCI journals have the characteristics of high concentration and experimental nature, while ordinary journals have the characteristics of diversity and interdisciplinary.

4. Conclusion

This study integrates the research progress trends in the acquisition of Mandarin tone by second language learners. The main research results emphasize the effectiveness of perceptual training, specific teaching strategies, and acoustic perception methods in addressing the difficulties faced by non-native speakers in learning Mandarin tone. Future research should prioritize (1) longitudinal studies of tonal acquisition trajectories across diverse linguistic backgrounds, (2) technological innovations (e.g., AI-driven tools, multimodal training) to optimize instructional outcomes, and (3) cross-linguistic studies examining the interplay between learners’ native language prosody and Mandarin tone processing. Bridging these gaps can ease globally accessible and more effective Mandarin tone instruction.

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