

# A Visualized CiteSpace Analysis on Eye-Tracking in Language Studies Abroad

Jinming Zhou<sup>1,\*</sup>, Jing Lin<sup>1</sup>

<sup>1</sup> Department of English, Ocean University of China, Qingdao, China

\* Corresponding author: Jinming Zhou (Email: zhoujm8671@163.com)

**Abstract:** This study analyzes the articles and reviews in eye-movement applied in language studies published between 2017 and 2021 with the CiteSpace software. Key research domains, research focuses and fronts, main researchers and key literature are analyzed with visualization tool accordingly from following aspects, that is, number of publications, countries, institutions, co-cited journals, literature, authors, co-occurrence of keywords and co-citation. Through analysis, this study found that the studies on eye-tracking in language studies have received continuous attention abroad and its research fields are mainly language comprehension, language acquisition and speech production. In addition, this paper briefly introduces the main researchers and key literature in this field, aims to provide researchers with referential literature.

**Keywords:** CiteSpace, Eye movement, Language.

## 1. Introduction

At the end of the 19th century, people began studying psychological activities by observing eye movements, progressing through two stages of traditional eye-tracking methods and contemporary approaches. With technological advancements, the performance of eye-tracking devices has improved, resulting in higher recording precision and faster data processing speeds (Bian et al., 2009). Eye-tracking technology has become a crucial method in psychological research, extensively applied in the field (Zhang & Wang, 2018). In language studies, eye-tracking serves as an experimental means to capture real-time eye movement trajectories when individuals process language information in visual or auditory contexts (Fang & Wu, 2021). This paper aims to analyze and summarize the application status of eye-tracking technology in international language research from 2017 to 2021 using the CiteSpace visualization and bibliometric analysis tool.

## 2. Data Sources and Processing

This study utilizes the visualization software CiteSpace developed by Professor Chen Chaomei of Drexel University, USA. Data is sourced from the Web of Science (WOS) database, adding "eye-tracking", "eye movement", and "language" as keywords. The publication period is limited to 2017-2021, and the search is conducted from the SSCI category. A total of 1352 documents, comprising articles and reviews, were retrieved. After excluding two articles from 2022 and one from 2016, a total of 1349 documents were considered. The study divides the period into five time slices, employing keyword co-occurrence analysis to outline the core areas of eye-tracking technology applied in language research. Additionally, keyword frequency is used to examine specific research hotspots over the years. Finally, through co-citation clustering, centrality, and citation frequency ranking, important researchers and core literature are analyzed.

## 3. Data Analysis and Discussion

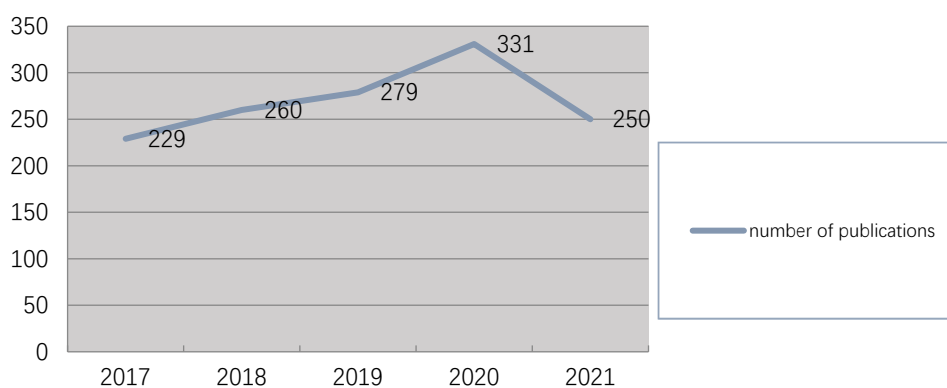
This paper aims to explore the application status of eye-

tracking technology in international language research, utilizing CiteSpace to reveal the research's forefront dynamics, including core topics, emerging fields, and disciplinary progress. The analysis involves institution, country, keyword, cited reference, and cited journal as node types. Time is sliced into five periods from January 2017 to December 2021, and the top 50 countries and universities are extracted for each time slice. After trimming the results and adjusting the threshold, the final visualized outcome is obtained.

### 3.1. Analysis of Publication Volume between 2017 and 2015

This article aims to explore the application status of eye-tracking technology in international language research, utilizing the CiteSpace analysis method. The study unveils the forefront dynamics of this research, encompassing core topics, emerging fields, and trends in disciplinary progress. The selected node types for analysis include institution, country, keyword, cited reference, and cited journal. The Time Slice functionality sets the time period from January 2017 to December 2021, with one year as a time partition. The Term Source functionality maintains default settings, and a threshold of TOP 50 is applied to extract the top 50 countries and universities in frequency ranking for each time slice. After pruning the results and adjusting the threshold, the study achieves the final visualized outcomes.

From Figure 1, it is evident that the publication volume has shown an overall upward trend in the last five years, reaching its peak of 331 articles in 2020. However, there was a slight decrease in 2021, potentially attributed to the impact of the global COVID-19 pandemic that emerged in 2020. Through an analysis of the publication volume, we observe a sustained increase in international attention towards the application of eye-tracking technology in research. However, a more in-depth analysis is required to understand the specific content of these related studies.



**Figure 1.** Graph of International Publications on the Application of Eye-Tracking Technology in Language Research (2017-2021)

**Table 1.** Analysis of Major Countries (Regions) and Institutions

Country	Publications	Centrality	University	Publications	Centrality
United States	511	0.32	Radboud University	51	0.02
United Kingdom	214	0.43	Potsdam University	34	0.19
Germany	176	0.17	University of Edinburgh	32	0.04
Netherlands	134	0.16	University of California, Davis	32	0.08
China	110	0.01	University of Illinois	29	0.06
Canada	99	0.04			
Spain	57	0.08			
Australia	57	0.09			
Scotland	48	0.05			

Table 1 presents the top ten countries and regions in terms of the number of publications on the application of eye-tracking technology in international language research from 2017 to 2021. The United States leads with 511 publications, indicating its world-leading position in research utilizing eye-tracking technology in the field of language studies. The United Kingdom follows closely in publication quantity, securing the top position in centrality, showcasing its pivotal role in this research domain. Countries with high centrality are primarily concentrated in Western European nations such as the UK and the US, signifying them as major contributors

to the application of eye-tracking technology in language research. Emerging countries like China, Canada, and Spain are increasingly becoming significant players in using eye-tracking technology for language research, showing an upward trend in both the quality and quantity of related studies. However, their publication volume and centrality are considerably lower than that of the United States, indicating that these countries still have some distance to cover in comparison to leading nations like the UK and the US in this research field.

**Table 2.** Ranking Information of Key Journals in International Eye-Tracking Research on Language

No.	Citation Count	Centrality	Impact Factor	Journal Name	Country
1	865	1.31	3.059	Journal of Memory and Language	USA
2	835	0.21	3.65	Cognition	Netherlands
3	640	0.26	3.051	Journal of Experimental Psychology-- Learning Memory and Cognition	USA
4	631	0.34	7.029	Psychological Science	USA
5	592	0	2.988	Frontiers in Psychology	Switzerland
6	554	0	3.468	Cognitive Psychology	USA

### 3.2. Key Journals

According to Table 2, prominent journals in the application of eye-tracking technology to language research primarily originate from the United States and the Netherlands. Notably, four out of the top six journals in terms of citation count are from the United States. In terms of centrality and citation count, the U.S.-based "Journal of Memory and Language" holds the top position, indicating its leading status in both quality and quantity of published articles. Looking at impact factors, the average impact factor among the six listed journals is 3.87. The U.S.-based "Psychological Science" holds the highest impact factor, followed by the Dutch journal "Cognition" and the U.S.-based "Cognitive Psychology." These six journals belong to the psychology category, and

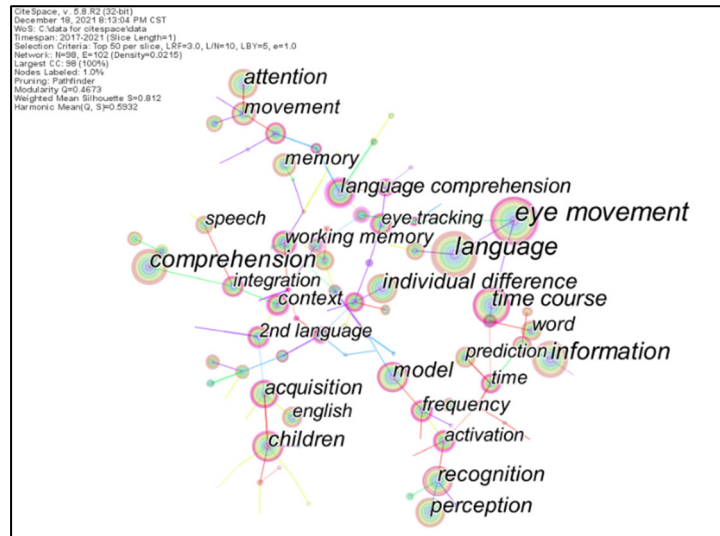
compared to other categories in the social sciences, psychology journals generally have higher impact factors, indicating a higher level of influence globally. Overall, the impact factors of these six journals have been increasing year by year, making them key journals in the international psychology category, with growing global attention to psychological research.

### 3.3. Research hotspots

Keywords, as the core and essence of an article, provide a highly summarized and concise overview of the article's main theme. Research hotspots in a field are often keywords with high co-occurrence frequencies (Xu Jinfen, 2015). This paper extracted keywords from the literature and created a co-occurrence knowledge map of keywords in eye-tracking

technology applied to language research using CiteSpace (see Figure 2). Keywords were classified by year to analyze the changing trends in hot topics in eye-tracking technology applied to language research over the past five years. The paper excluded some broad terms such as "performance" and "information," as well as country names like "Spanish." The

top seven keywords with the highest frequencies each year were selected to represent the research's hot topics. It's worth noting that in 2019, only three keywords were prevalent, and in 2021, after excluding "Spanish," there were six keywords (see Table 3 for details).



**Figure 2.** Co-occurrence of Keywords in Research Regarding the Application of Eye-Tracking Technology in International Language Research

Figure 2 illustrates that the top 20 co-occurring keywords, based on frequency, are as follows: eye movement, language, information, comprehension, time course, individual difference, children attention, recognition, perception, model, acquisition, frequency, context, memory, working memory, word, activation, English, speech, integration. Among the keywords with lower co-occurrence frequencies but the highest centrality, the top four are: event-related potential, language comprehension, context, speech perception. This indicates that in the past 5 years, research utilizing eye-tracking technology in language studies primarily focuses on

second language acquisition, involving both adults and children, with special attention to children's learners' attention and individual differences. On the language level, the research is concentrated on language comprehension, language acquisition, and speech production. On the psychological level, there is a considerable amount of research involving working memory, perception, recognition, activation, and more. In terms of research methods, in addition to eye-tracking technology, there is also a combination of eye-tracking and electroencephalogram (EEG) techniques.

**Table 3.** Hot Topics in International Eye-Tracking Technology Applied to Language Research (2017-2021)

No.	2017	2018	2019	2020	2021
1	eye movement	predictability	sentence	skill	age
2	language	word recognition	Sensitivit-y	word frequency	Joint Attenti-on
3	Comprehens-ion	brain potential	Develop-ental dyslexia	vocabulary	gender
4	time course	N400		bilingual	syntax
5	Individual-difference	discrimination		learner	length
6	children	experience		Segmentat-eon	Visual-world
7	attention	older adult		exposure	

According to Table 3, it is evident that in 2017, the research focus was on the impact of individual differences on language comprehension, with a specific emphasis on the child population. The research theme in 2018 became more nuanced, shifting from comprehension to word recognition and ambiguity resolution, with increased attention on adult learners. Research methods progressively diversified, transitioning from the sole use of eye-tracking techniques to

a heightened focus on combining eye-tracking with electroencephalography (ERP). ERP, also known as Event-related Potential, involves analyzing the brain's internal mechanisms during language processing by recording brain electrical responses induced by presented stimuli. The N400 component serves as an electroencephalographic indicator for studying contextual effects in sentence processing, manifested as a negative wave in response to words

incongruent with the context during sentence reading. In 2019, attention continued to be directed towards language comprehension, particularly emphasizing research on sentence processing and focusing on special populations, such as individuals with developmental reading disorders. The year 2020 prioritized bilingual learners, with a linguistic focus on topics like vocabulary segmentation and language proficiency. In 2021, the study of syntax in language became a focal point, and the visual context paradigm in eye-tracking techniques gradually gained researchers' attention. The visual context paradigm, proposed by Cooper in 1974, was initially designed to investigate the processing of spoken language comprehension and cognition. However, it wasn't until 1995, when Tanenhaus and others applied this paradigm to study the integration of visual context and language information in spoken language comprehension, that it garnered international scholars' interest (Yan Guoli et al., 2010). In summary, the research hotspots over the past five years have predominantly centered around language comprehension, with increasingly refined themes encompassing comprehension, vocabulary recognition, ambiguity, word segmentation, sentence length, syntax, among others. Furthermore, research methodologies and paradigms have witnessed a growing diversification.

### 3.4. Key Researchers and Core Literature

The analysis of focal topics aids in comprehending widely acknowledged themes within this research domain. Researchers embarking on studies should concentrate on significant scholars and pivotal literature within distinct themes. Analyzing the frequency of author citations provides valuable insights into the prominent scholars and research themes. Constructing an author co-citation graph, with cited authors as nodes, enables us to identify influential researchers. In this study, we extracted the top 8 authors based on citation frequency and centrality, as presented in Table 4. The listed scholars are closely affiliated with the field of psychology.

Keith Rayner, a professor in the psychology department at the University of California, holds the highest citation frequency and centrality. His primary research revolves around the cognitive processes in the human brain during language comprehension, production, and situational awareness. Dale J. Barr, affiliated with the Institute of Neuroscience and Psychology at the University of Glasgow, focuses on cognitive science, speech comprehension, and statistical methodologies. Adrian Staub concentrates on language production and comprehension, particularly in syntax structures, often employing eye-tracking techniques in experiments. Falk Huettig explores the influence of culture and environment on shaping the brain. Altmann GTM's research is centered on sentence processing and event cognition. Professor Kutas Marta from the Department of Cognitive Science at the University of California specializes in understanding how context shapes language and memory processing, primarily utilizing electroencephalography (EEG) as a research technique.

The majority of these eight scholars employ EEG, eye-tracking, or behavioral techniques in their research, focusing on the intersection of psycholinguistics and cognitive science.

Additionally, we have compiled a list of the top 10 highly cited papers (see Table 5), offering a glimpse into the hot topics in eye-tracking technology applied to language research from a literature citation perspective. The first two highly cited papers investigate models for eye movement data

analysis, specifically Linear Mixed-Effects Models (LMMs), which prove effective in handling unavoidable variability in participant and stimulus sampling processes across most eye-tracking experiments (Fang Shaohua, Wu Zhiyi, 2021). The remaining four highly cited papers predominantly address predictive studies within the realm of language comprehension, aligning closely with the findings from Citespace graph analysis. In conclusion, predictive research in language comprehension has emerged as a focal point in recent years, emphasizing the imperative role of mastering eye-tracking data processing and analysis methodologies in yielding meaningful results.

**Table 4.** Statistics of Authors' Cumulative Citation Frequency

Frequency	Centrality	Aauthor
405	0.25	RAYNER K
341	0.24	Barr DJ
106	0.17	Staub A
201	0.13	Tanenhaus MK
400	0.12	Bates D
202	0.09	Huettig F
195	0.09	Altmann GTM
124	0.09	Kutas M

## 4. Conclusion

This study employed CiteSpace software and the Web of Science database to conduct a comprehensive analysis of the application of eye-tracking technology in language research. The analysis encompassed publication trends, keyword co-occurrence, and co-citation networks. The findings reveal a growing international interest in using eye-tracking technology for language research over the past five years, with a primary focus on language comprehension. The research emphasis is further subdivided into lexical and syntactic aspects of comprehension, exploring predictive processing, ambiguity resolution, and recognition issues.

On the methodological front, a trend towards combining eye-tracking technology with other research methods for diverse validation is observed. The study also introduces key publications, journals, influential researchers, and significant works in the field.

It is essential to acknowledge the limitations of this study, including the relatively short timespan of the analyzed literature (five years) and the use of only the Web of Science database, which predominantly comprises foreign literature. Future research in this field could extend the temporal scope to a decade and include domestic literature, providing a more comprehensive comparative analysis of international and domestic research trends and developments.

## References

- [1] Aryadoust, V., & Ang, B. H. (2021). Exploring the frontiers of eye tracking research in language studies: a novel co-citation scientometric review. *Computer Assisted Language Learning*, 34(7), 898-933.
- [2] Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255-278.
- [3] Bates, D., Machler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 68(3), 255-278.

- [4] Cooper, R. M. (1974). The control of eye fixation by the meaning of spoken language: a new methodology for the real-time investigation of speech perception, memory, and language processing. *Cognitive Psychology*, 6, 84–107.
- [5] Bian, Q., Qi, W., & Liu, Z. F. (2009). Review of contemporary eye-tracking recording technology. *Psychological Research*, 2(1), 34-37.
- [6] Deng, L. M., & Zhou, Y. (2020). Visualization analysis of international academic discourse research based on CiteSpace. *Foreign Language Teaching*, 41(01), 54-58.
- [7] Fang, S. H., & Wu, Z. Y. (2021). Review of "Eye Movements in Second and Bilingual Contexts: A Research Overview and Technical Guide". *Foreign Language Teaching and Research*, 53(04), 628-632.
- [8] Qin, L. L., Guo, Q. R., Yao, L., & Niu, B. G. (2021). Visualization analysis of foreign social and cultural theory research based on CiteSpace (1996–2020). *Journal of Jiangsu Ocean University (Social Science Edition)*, 19(01), 92-103.
- [9] Yan, G. L., Wu, J. G., Hu, Y. W., & Bai, X. J. (2010). A review of current paradigms in eye movement research on reading. *Psychological Science Progress*, 18(12), 1966-1976.
- [10] Yuan, Z. M., Yi, B. S., & Zhang, Y. N. (2020). Foreign eye-tracking research in linguistics: current status and prospects (1934–2020). *Foreign Languages in China*, (06), 46-53.
- [11] Xu, J. F., & Nie, R. (2015). Dynamic visualization analysis of international research on second language writing based on CiteSpace (2004–2014). *Computer-Assisted Foreign Language Education*, (04), 3-9.
- [12] Zhang, X., & Wang, J. H. (2018). CiteSpace visual analysis of the application of eye-tracking technology in language research in China. *Journal of Hunan University (Social Science Edition)*, 32(05), 107-112.