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Research Article

Global Research Trends on Cognitive Neuroscience: A Scientometric Visualization

Rima Hazarika, K G Sudhier

Department of Library and Information Science, Central University of Tamil Nadu, Thiruvarur, Tamil Nadu, INDIA.

ABSTRACT

Cognitive Neuroscience is a scientific field that studies the neural mechanisms underlying cognitive processes, such as perception, attention, memory, language, and decision-making. The present study explores the research productivity of cognitive neuroscience from 2013 to 2022 based on the Scopus database. 11,840 records were used to identify the most productive authors, preferred journals, co-occurrence of keywords, highly cited articles, funding agencies, countries' collaboration, and trend topics. Data analysis was performed using VOSviewer, R software, and MS Excel. The study indicates that most publications occurred in 2022, totaling 1,386 documents. Among the authors, Wang, Y. stands out as the most productive, contributing 1.42% of the publications. Frontiers in Psychology journal emerges as the most highly influential one. The study also reveals that the United States is the most collaborative nation, with 4,560 documents co-authored with other countries. The keyword analysis highlights "Neuroscience" as the most frequently occurring term, appearing 1,094 times. The National Institutes of Health (NIH) takes the lead as the top funding agency. This study holds great value for researchers and policymakers as it provides insights and information to develop strategies for further research and collaborations in the field.

Keywords: Scientometrics, Cognitive neuroscience, Collaborations, Co-Occurrence, Network, Vosviewer.

Correspondence:
Ms. Rima Hazarika
Department of Library and Information Science, Central University of Tamil Nadu, Tamil Nadu, Thiruvarur, INDIA.
Email: rimahazarika123@gmail.com

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INTRODUCTION

Cognitive neuroscience studies human mental functions and their underlying neural substrates. It examines the biological processes of human cognition, particularly the relationships between brain structure, activity, and cognitive function. This field aims to determine how the brain functions and achieves optimal performance (Johnson, 2008). Cognitive neuroscience intersects psychology and neuroscience and overlaps with physiological psychology, cognitive psychology, and neuropsychology. It combines cognitive psychology theories and computational modeling with experimental data on the brain (Nature Research, 2021).

Scientometrics, also known as the science of science, combines mathematical, bibliographical, and statistical methods to quantitatively analyze all carriers of knowledge. This approach has advantages in evaluating academic achievements and predicting research trends. Scientometrics involves measuring and assessing science, innovation, and progress (Oyewola & Dada, 2022). The most critical research issues include effect estimation, creating reference collections of articles to explore the impact of journals and organizations, understanding scientific citations, technical field mapping, and creating markers for use in procedural and administrative settings.

Information mapping and visualization are techniques used to understand the structures and interrelationships of thousands of documents easily. These visual tools abstract, summarize, and present large volumes of data, facilitating interactive exploration by users. Some notable software has been developed specifically for mapping and visualization (Sangam & Mogali, 2012). This software enables users to design maps, visually represent scientific research based on citation data, and study the structure, time, and dynamics of various disciplines. Most of this software is based on modern algorithms, mathematical and statistical methods, graph theory, network science, etc. Consequently, many visualization tools have been developed for scientometric studies in recent years, which improves the timeliness, accessibility, and reproducibility of documentary research. Therefore, in this paper a network visualization of global literature published on Cognitive Neuroscience research. Through the use of various scientometric indicators and bibliometric networks, this study aims to assist researchers, institutions, and policymakers in

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making well-informed decisions regarding resource allocation and the advancement of research in cognitive neuroscience.

REVIEW OF LITERATURE

Many scientometric studies have been conducted in various fields, while only a few studies have been conducted on cognitive neuroscience research, both globally and nationally. Some relevant studies in the directions mentioned below are discussed here. The dynamics of neuroscience research in the Kingdom of Saudi Arabia (KSA) from 2013 to 2018 were selected from the SciVal function of the Scopus database (Alhibshi *et al*., 2020). Saudi Arabia is ranked 39th for publishing neuroscientific research in the world. The number of papers published annually increased from 123 to 332 between 2013 and 2018. King Saud University and King Abdul Aziz University and their corresponding regions, namely the West and Central regions, are the main contributors to the publications. Another study examines the trends in exosome research in neuroscience using visualization tools and data collection from the Web of Science between 2005 and 2021(Long *et al*., 2022). It collected 21 high-frequency keywords from 856 included articles and identified 5 clusters through biclustering analyses. The results of the co-citation analysis revealed some crucial works that contributed to the development of exosome research in neuroscience. A bibliometric study on Latin American scientific production in cognitive neuroscience were extracted from SCOPUS between 2012 and 2022 (Zayas-Fundora & Vázquez-Ortiz, 2022). A search was conducted for data provided by Scimago Journal and Country Rank on publications in the "Neurosciences" field within the "Latin America" region and the "Cognitive Neurosciences" category. In total, 3,717 documents were published, with 2022 being the year with the most published documents. For the bibliometric analysis and network visualization of cognitive aging research, 3,779 papers were retrieved from the Scopus database from 1956 to 2021(Othman *et al*., 2022). The United States emerged as the leading contributor to cognitive aging research. The most prolific researcher, with the highest number of publications, was Deary, I. J. Furthermore, the collaborative index demonstrated an increasing trend starting from 1980 onwards. Notably, "Frontiers in Aging Neuroscience" ranked as the most prestigious journal in cognitive aging research. A bibliometric analysis of 1,462 published articles on the Cognitive neuroscience of aging from the Web of Science (WOS) investigated highly influential and potential research topics and theories related to CNA and essential brain areas involved in CAN from 2000 to 2021 (Jiang *et al*., 2023). The results revealed that "memory" and "attention" were the primary research topics, evolving towards an fMRI-oriented stage. The scaffolding theory and the hemispheric asymmetry reduction in older adults' model played a central role in CNA, characterizing aging as a dynamic process and highlighting compensatory relationships between different brain areas. Age-related changes were consistently observed in temporal areas, especially the hippocampus, parietal, and frontal lobes, and cognitive declines established compensation relationships between the anterior and posterior regions.

It is observed that, there is no scientometric analysis has been conducted on the cognitive neuroscience using the Scopus database. To address this significant gap in the existing literature, this study comprehensively analyzed the global landscape of scientific publications on cognitive neuroscience research from 2013 to 2022. This analysis was carried out utilizing VOSviewer, Biblioshiny, and Excel tools. The primary aim of this analysis is to provide valuable insights that can benefit the academic and scientific community, specifically aiding researchers in quickly identifying the prevailing research hotspots and cutting-edge trends within the field of cognitive neuroscience in recent years.

Based on the previous research, this study focuses on two primary research questions:

What are the silent features of global research derived from the Scopus database?

What are the emerging research trends in the domain of cognitive neuroscience?

OBJECTIVES

The main objectives of the study are as follows:

To study the year-wise growth rate of the total publications on research trends.

To find the prolific author and source based on the number of publications.

To explore the co-occurrence of keywords in cognitive neuroscience.

To identify the funding agencies and trending topics.

To analyse the highly cited scientific literature.

To understand the network visualization of bibliographical coupling among authors.

METHODOLOGY

This study is based on data downloaded from Scopus, the most comprehensive bibliographic and citation information database, covering 2013 to 2022. The research focused on cognitive neuroscience, utilizing search documents with full probabilities. The following search string was used to collect the data: (TITLE-ABS-KEY (Cognitive Neuroscience) OR TITLE-ABS-KEY ("Neuroscience") OR TITLE-ABS-KEY ("Brain Science")) AND PUBYEAR > 2012 AND PUBYEAR < 2023). The search strategy yielded a total of 11,842 records. The complete bibliographic details were extracted, including title, author, source, year, affiliation, citation information, and other relevant information (Choubey *et al*., 2023). The data was

imported in CSV format, along with all bibliographic details, and then converted to MS Excel for data analysis and the application of various bibliometric techniques (Barui & Mazumder, 2023). These techniques include VOSviewer (van Eck & Waltman, 2010) and Biblioshiny (Aria & Cuccurullo, 2017), which were implemented using R-studio and Microsoft Excel.

DATA ANALYSIS AND DISCUSSION

Annual Growth of Production

Research productivity was assessed by evaluating the quality and quantity of publications produced by the researchers. These publications included research articles published in academic journals, conference proceedings, books, book chapters, monographs, patents, and commentaries(Creswell, 1986)(Barui & Mazumder, 2023). Over the study period from 2013 to 2022, 11,840 publications with 237,375.57 citations were published in the field of Cognitive Neuroscience. Figure 1 illustrates the annual growth of publications in Cognitive Neuroscience. Data analysis reveals that the highest number of publications was observed in 2022, i.e., 1,386 (11.71%), followed by 2021 with 1,317 (11.12%) publications, and the lowest number of articles, 1,006 (8.50%), published in 2013. Therefore, the publication growth is not uniform throughout the year. The year 2018 recorded the highest positive growth rate at 13.68%, while 2019 had the highest negative growth rate at -10.34%. The value of the Average Annual Growth Rate (AAGR) is 20.05%.

Document type publications in Cognitive Neuroscience

The productivity of researchers in Cognitive Neuroscience spans 13 types of publication media, including journal articles, reviews, book chapters, conference papers, books, editorials, notes, erratum, short surveys, letters, conference reviews, data papers, and undefined documents. These publications were analysed for 10 years (2013-2022). The analysis reveals that the highest number of records, 6258 (52.85%), were published as journal articles, followed by review papers with 2102 (17.76%), book chapters with 1128 (9.53%), conference papers with 922 (7.79%), books with 436 (3.69%), editorials with 323 (2.73%), notes with 310 (2.62%), erratum with 174 (1.47%), short surveys with 102 (0.87%), letters with 47 (0.4%), conference reviews with 30 (0.26%), and data papers with 7 (0.1%). The lowest number of records, 3 (0.1%), was published in the "Undefined" category. These various types of documents significantly impact the information access patterns of users and research scholars up to a great extent.

Subject Profile

According to Scopus, the cited publications in cognitive neuroscience were categorized into 27 subject categories. The research contributions in these subfields varied widely, ranging from 2 to 4734 articles. It is observed that the majority of publications are in the field of neuroscience, with 4734 (22.7%), followed by medicine, with 3276 (15.8%), and psychology, with 3251 (15.6%), as illustrated in Figure 2. The remaining analysis of cognitive neuroscience research results revealed that 9597 papers (0.02%) were distributed across various other disciplines. These included computer science, social sciences, arts and humanities, biochemistry, genetics and molecular biology, engineering, multidisciplinary, mathematics, agricultural and biological sciences, physics and astronomy, business, management and accounting, health professions, immunology and microbiology, pharmacology, toxicology, and pharmaceutics, economics, econometrics, and finance, nursing, decision sciences, chemical engineering, environmental science, chemistry, materials science, energy, earth and planetary sciences, veterinary, and dentistry.

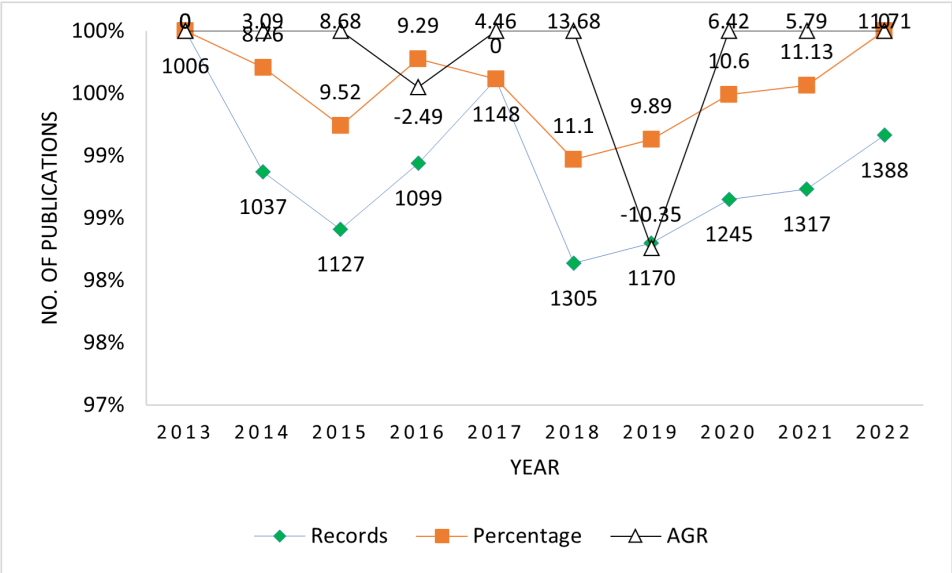

Figure 1: Annual Growth of Publications.

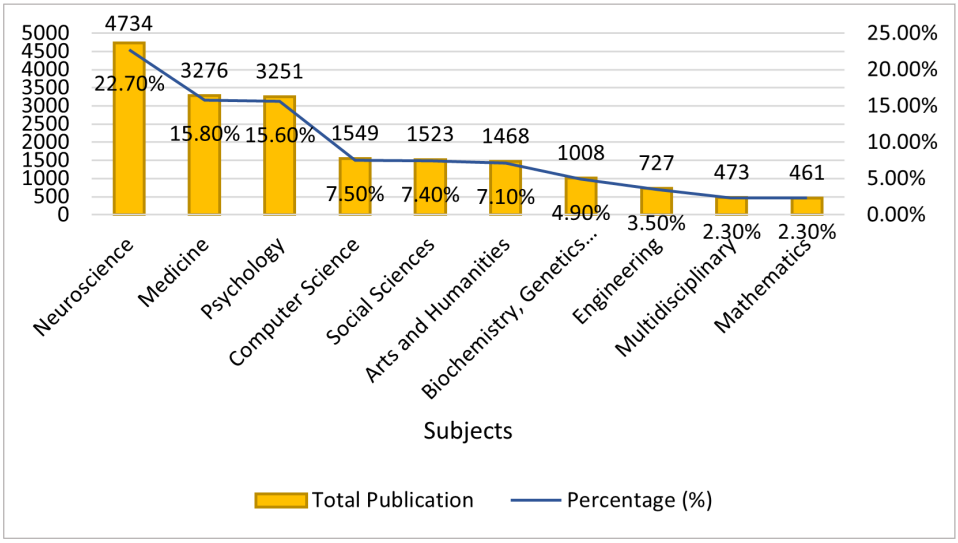

Figure 2. Top 10 Subject profile of cognitive neuroscience.

Table 1: Top 10 Prolific Authors.

Rank	Author	NP	TC	*h*_index	PY_start
1	Wang Y	51(0.14%)	363	11	2013
2	Wang J	37(0.11%)	409	11	2014
3	Li X	37(0.11%)	309	9	2014
4	Zhang Y	36(0.10%)	319	10	2013
5	Bassett DS	33(0.10%)	1676	17	2014
6	Zhang J	32(0.09%)	292	9	2014
7	Balconi M	28(0.08%)	134	7	2016
8	Barch DM	27(0.08%)	852	16	2013
9	Barbey AK	27(0.08%)	765	15	2013
10	Liu Y	27(0.08%)	159	7	2013

(NP: Number of Publications; TC=Total Citations; PY=Publication Year).

Prolific Authors

The highly productive authors in cognitive neuroscience are listed in Table 1, along with their *h*-index, the total number of citations, and the total number of publications. Y Wang leads the table with the highest, i.e., 51(0.14%) publications, followed by J Wang and X Li with 37(0.11%) publications. However, according to the number of citations and *h*-index received, DS Bassett has the maximum, i.e., 1676 citations and 17 *h*-index, followed by DM Barch with 852 citations and 16 *h*-index. D. M. Barch, A. K. Barbey, and Y. Liu have published the least 27(0.08%) publications among the top 10 authors. D. M. Barch, A. K. Barbey, and Y. Liu have published the least publications, 27(0.08%) among the top 10 authors. The majority of these authors started their publications in 2013, respectively.

Highly Journals

A total of 10,857 publications were published in 2921 journals. Table 2 indicates the high-ranking journals' total publications, citations, *h*-index, publication year, and publisher details. It is found that the journal entitled "*Frontiers in Psychology*" (Frontiers Media S.A.) published the highest number of publications, with 249 (2.30%) papers, 4998 citations, and an h-index of 39. It was followed by "*Frontiers in Human Neuroscience*" (Frontiers Media S.A.) with 235 (2.17%) publications and 6418 citations, obtaining the *h*-index of 47. The journal titled "*Neuroimage*" (Academic Press Inc.) is ranked third with 193 (1.78%) publications, 8454 citations, and an *h*-index of 46. Among the top 10 journals, "*Neuroscience and Biobehavioral Reviews*" (Elsevier Ltd.) received the highest *h*-index of 48. On the list, "*Scientific Reports*" (Nature Publishing Group) published the least number of papers, 85 (0.79%). Hence, a maximum number of journals started their publication in 2013.

Bibliographic Coupling of Authors

The bibliographic coupling of the contributing authors is presented in Figure 3. The authors were divided into 6 clusters in the network based on the number of collaborations and

Table 2: Top 10 Prolific Journals in Cognitive Neuroscience.

Rank	Journal	Publication	NP	TC	*h*_index	PY_start
1	Frontiers in Psychology	Frontiers Media S.A.	249(2.30%)	4998	39	2013
2	Frontiers in Human Neuroscience	Frontiers Media S.A.	235(2.17%)	6418	47	2013
3	Neuroimage	Academic Press Inc.	193(1.78%)	8454	46	2013
4	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Springer Science+BusinessMedia	139(1.29%)	296	9	2013
5	Neuroscience and Biobehavioral Reviews	Elsevier Ltd.	130(1.20%)	7134	48	2013
6	Trends in Cognitive Sciences	Elsevier Ltd.	109(1.01%)	8393	47	2013
7	iScience	Elsevier Inc.	106(0.98%)	667	15	2018
8	Frontiers in Neuroscience	Frontiers Media S.A.	105(0.97%)	2590	27	2013
9	Journal of Cognitive Neuroscience	MIT Press Journals	96(0.89%)	2173	24	2013
10	Scientific Reports	Nature Publishing Group	85(0.79%)	953	18	2014

(NP: Number of Publications; TC=Total Citations; PY=Publication Year).

associations between each author. The size of the circle represents the number of documents. This visualization map identifies six different clusters based on this distribution. The three significant clusters on this network are red, green, and blue. Out of 11,090 authors, 8,765 met the threshold of 300 items connected, resulting in 6 clusters with 29,992 links and a total link strength of 110,770. Among the 6 clusters, the largest cluster consists of 78 authors (marked in red), followed by the second cluster (green) consists of 67 authors; the third cluster (blue)consists of 60; the fourth cluster (yellow) consists of 39; the fifth cluster (purple) consists of 29; and the sixth cluster (light blue) consists of 27 authors, respectively.

Network of Keywords Co-occurrence

The keyword co-occurrence network is visualized using bibliographic data extracted from the Scopus database on cognitive neuroscience. The size of the circle indicates how often the keyword appears; the more significant the process, the more often the keyword appears. A total of 20,513 keywords had a minimum co-occurrence of 4, as illustrated in Figure 4. Among these, 2,779 keywords met the threshold criteria. The network consists of 500 keywords grouped into 11 clusters, with 14,036 links and 26,265 link strengths. Among the keywords, "Neuroscience" appears most frequently with 1094 occurrences and has a total link strength of 2963. It is followed by "Cognitive Neuroscience," with 919 occurrences and a total link strength of 2157. Both of these keywords are part of the same cluster comprising 1 cluster.

Trending Topics

Keywords indicate discussion topics in research documents and help us to find relevant literature in the field. Figure 5 represents trend areas in cognitive neuroscience research between 2013-2022. Year q1, year med, and year q3 represent various periods. A trending topic, say a bubble, indicates that at least one document on a trending topic was published in a given year, whereas bubble size is proportional to the number of articles published on the topic in that given period (Dhiman *et al.*, 2023). It shows that 18 keywords have been trending for five to six consecutive years, while 9 keywords are for three to four years. The keywords 'named inventories, questionnaires and rating scales' appeared 14 times between 2013 and 2014, 'brain mapping' appeared 1486 times between 2015 and 2020, and 'attention deficit hyperactivity disorder' appeared 26 times between 2021 and 2022.

Collaborative Networks by Country

The world collaboration mapping shows the performance of research collaborations between various countries in cognitive neuroscience. Figure 6 illustrates the contribution of authors in India as well as other countries. The color on the map shows the intensity of the relationship, i.e., light color indicates a weak relationship, dark color indicates a stronger relationship and grey color indicates no relationship. When evaluated in terms of country connections, the United States has the strongest collaboration with the United Kingdom (303), followed by the United States collaboration with Canada (244), and the United States with Germany (198), respectively.

Funding Agencies

The profile of the top 10 funding agencies in cognitive neuroscience over the period (2013-2022) was extracted from the Scopus database. The analysis reveals that a large number of funding bodies have been recognized by research publications on cognitive neuroscience. A total of 160 funding bodies were found, of which the top 10 funding agencies were listed in Figure 7. The National Institutes of Health funded the maximum number of publications, with 758 (5.07%), followed by the National Institute of Mental Health with 597 (4.00%), and the National Science Foundation with 413 (2.76%) publications, respectively.

Highly Cited Scientific Literature

Table 3 displays the top 10 cited scientific literature on cognitive neuroscience, covering data such as the title of the scientific literature, source title, author(s), publication year, total citations, and citations publication year. From the analysis, it was found that A Clark's article 'Whatever next? Predictive Brains, situated agents and the Future of cognitive science', published in the *Behavioral and Brain Sciences* Journal, had the highest number of citations with 2512 total citations (228.36 per year) in 2013. B. N. Cuthbert and T. R. Insel authored the second top-cited scientific literature. They published the article 'Toward the future of psychiatric diagnosis: the seven pillars of RDoC' in the *BMC*

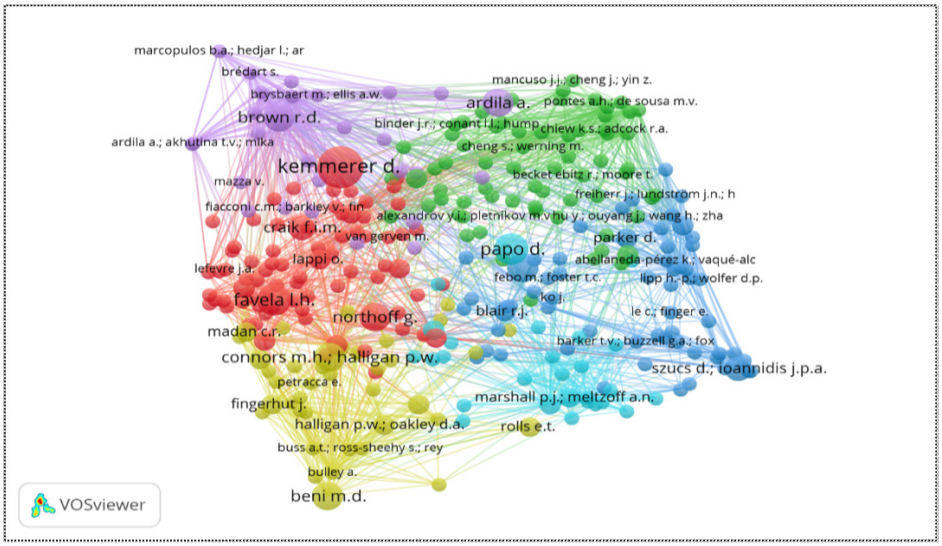

Figure 3: Bibliographic Coupling of Contributing Authors.

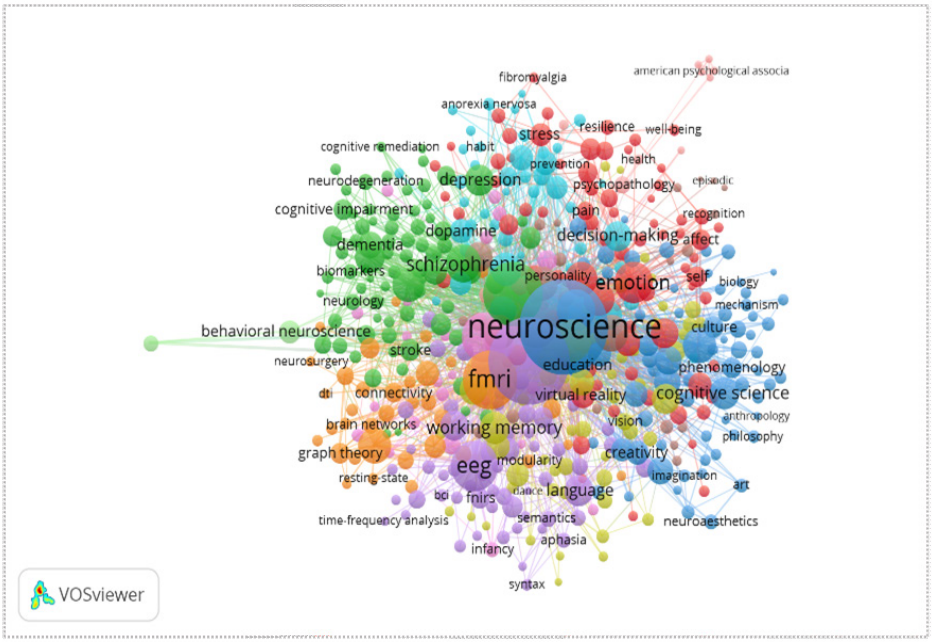

Figure 4: Network Visualization of Keywords Co-occurrence.

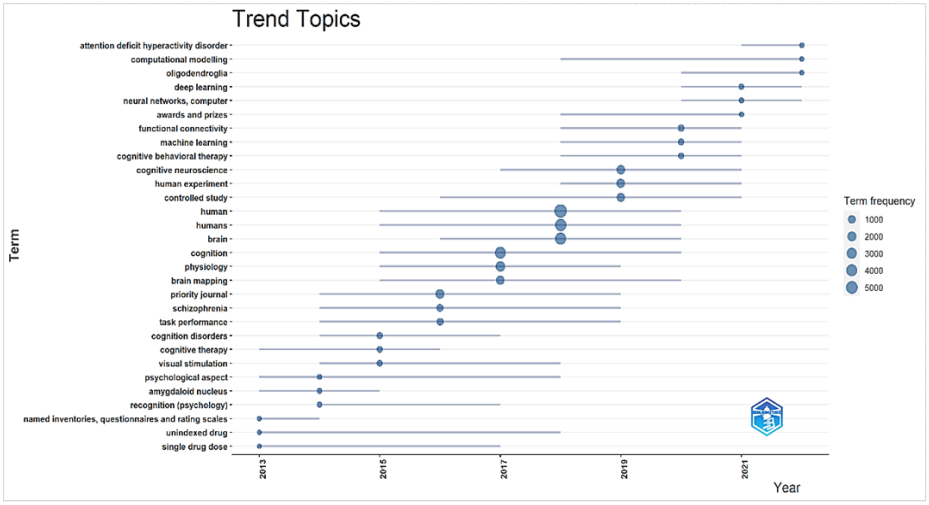

Figure 5: Keywords Trend topics Collaborative Networks by Country.

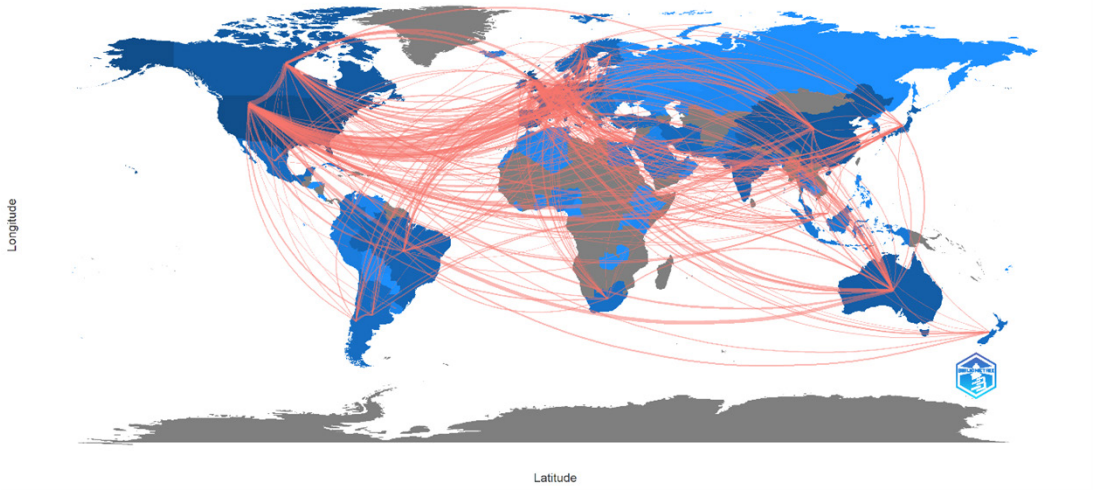

Figure 6: Collaboration frequency at the global level.

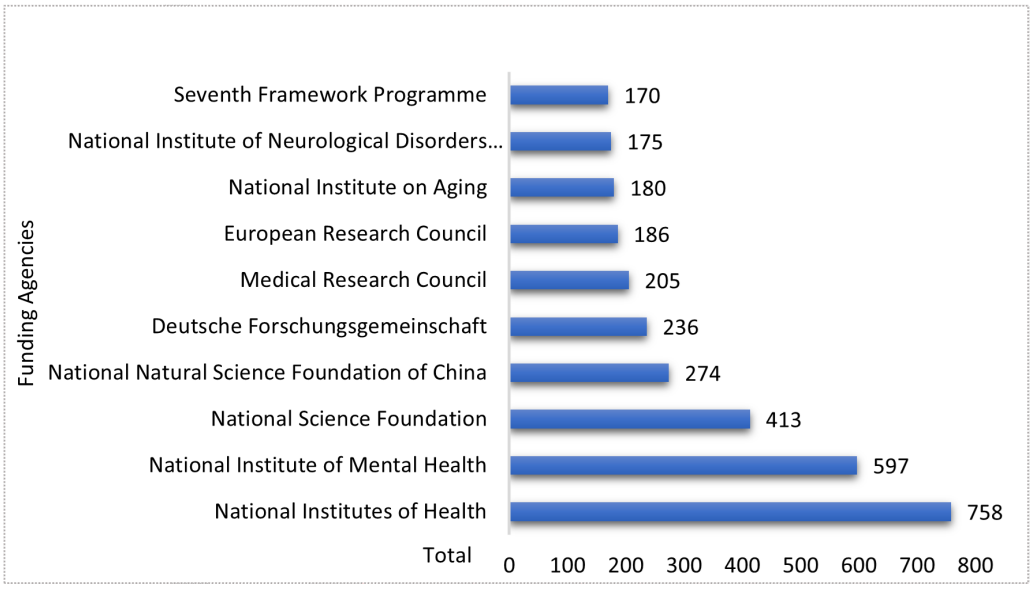

Figure 7: Highly funding agencies in cognitive neuroscience.

Table 3: Highly cited scientific literature.

Sl. No.	Paper	Title	Source	Year	Total Citations	TC per Year
1	Clark, A.	Whatever next? Predictive brains, situated agents, and the future of cognitive science	Behavioral and Brain Sciences	2013	2512	228.36
2	Cuthbert, B. N. and Insel, T. R.	Toward the future of psychiatric diagnosis: the seven pillars of RDoC	BMC Medicine	2013	1674	152.18
3	Jones D.K. *et al.*	White matter integrity, fiber count, and other fallacies: The do's and don'ts of diffusion MRI	NeuroImage	2013	1570	142.73
4	Park, H. and Poo, M.	Neurotrophin regulation of neural circuit development and function	Nature Reviews Neuroscience	2013	1272	115.64
5	Tang, Y-Y. *et al.*	The neuroscience of mindfulness meditation	Nature Reviews Neuroscience	2015	1222	135.78
6	Shenhav, A.	The Expected Value of Control: An Integrative Theory of Anterior Cingulate Cortex Function	Neuron	2013	1196	108.73
7	Cavanagh, J. F. and Frank, M. J.	Frontal theta as a mechanism for cognitive control	Trends in Cognitive sciences	2014	1131	113.10
8	Bari, A. and Robbins, T. W.	Inhibition and impulsivity: Behavioral and neural basis of response control	Progress in Neurobiology	2013	1109	100.82
9	Andrews-Hanna, J. R.	The default network and self-generated thought: component processes, dynamic control, and clinical relevance	Annals of the New York Academy of Sciences	2014	1079	107.90
10	Owen, M. J.	Schizophrenia	The Lancet	2016	957	119.63

Medicine Journal, which received 1674 citations (152.18 per year) in 2013. The article on 'Schizophrenia,' published in *The Lancet*, had the least citations, with 957 in 2016.

FINDING AND CONCLUSION

The present study aims to visualize the research field of cognitive neuroscience based on the Scopus database from 2013 to 2022. Data analysis was performed using VOSviewer and Biblioshiny through R-studio software. The study includes a scientific mapping analysis of the most prolific authors and journals. Additionally, network analysis was conducted to visualize bibliographical coupling and co-occurrence of keywords. The cluster views, which illustrate the spatial structures of networks, are shown in VOSviewer.

It is evident from the research output that 11,840 publications on cognitive neuroscience were published during the study period. The highest number of publications was recorded in 2022, while the lowest was in 2013. Throughout the period, author Y. Wang published the most articles, and the journal "Frontiers in Psychology" was the most preferred publication. The United States exhibited the highest collaboration with 4,560 documents in cognitive neuroscience. 'Neuroscience' is the frequently used keyword utilized by the researchers. The National Institutes of Health provides the highest funding agency support in cognitive neuroscience. One highly cited scientific literature titled "Whatever next? Predictive brains, situated agents, and the future of cognitive science" is published in the Behavioral and Brain Sciences Journal by author A. Clark, garnering 228.36 citations per year.

Further study revealed that the United States maintains the strongest collaboration with the United Kingdom regarding country connections. Keyword-based trending topics analysis showed that 'Cognitive Neuroscience' is the most prominent keyword of interest in scientific studies, gaining the most attention among researchers. This research involves a detailed examination of cognitive neuroscience by analyzing its scientific literature growth and publishing trends. The study employs

several bibliometric techniques, such as identifying key journals, assessing author productivity trends, exploring subject areas, examining major funding sources, and addressing other relevant aspects. These analytical methods provide valuable insights into the worldwide landscape of cognitive neuroscience and enhance the comprehension of its development.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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