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Bibliometric and Visual Analysis of the International Research on Dysarthria in Linguistics

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Abstract: Dysarthria is a key interdisciplinary research focus in phonetics and medicine, with significant research and application value. Using the bibliometric tools CiteSpace and Bibliometrix, this study analyzes 1,850 dysarthria-related papers from the WOS Core Collection, examining trends and hotspots from 1966 to 2024 from a linguistic perspective and predicting future developments. Key findings include: First, publications on dysarthria in linguistics have steadily increased, with the Journal of Speech, Language, and Hearing Research emerging as a highly cited journal, and Murdoch B.E. and Kent R.D. as influential authors. Second, research focuses primarily on disease types, speech characteristics, and rehabilitation methods. In the last five years, bulbar, deep learning, and speech recognition have become emerging topics. Lastly, the integration of artificial intelligence and big data is suggested for future research to enhance the analysis of patients' speech characteristics and improve rehabilitation technologies.

Keywords: Dysarthria; Citespace; Bibliometrix; Psycholinguistics

1. Introduction

Dysarthria is considered one of the most pervasive communication disorders within early childhood development [1]. Though the etiology, especially for functional articulation disorder, is not fully comprehended and complex [2], the importance of the effect dysarthria has on language development is immense. Dysarthria can have a major impact on children's psychological development in relation to low self-esteem, social difficulties, and personal character development [3]—areas in which there is general consensus. This can also lead to social anxiety and psychological pressure in school settings where smooth communication is indispensable [4]. Generally speaking, dysarthria encompasses pronunciation, voiced or voiceless sound, resonance, and prosody abnormalities because of neuromuscular system pathological change or structural abnormality of articulatory organs [5].

From a broad perspective, dysarthria can be divided into three kinds: motor dysarthria, organic dysarthria, and functional dysarthria [6]. It presents as changes in speech auditory characteristics, including strain in voicing, inaccurate articulation or phonation, unclear articulation, abnormal loudness, tone, rate, rhythm, and excessive nasality. More narrowly, dysarthria refers to motor dysarthria. Common etiologies include stroke, cerebral palsy, brain tumors, amyotrophic lateral sclerosis, myasthenia gravis, cerebellar injury, Parkinson's disease, and multiple sclerosis. The pathological basis of dysarthria lies in motor impairments [7].

Traditional pathophysiological dysarthria research, for instance, into corticolingual projections, has tended to focus on how specific neural pathways lead to impaired speech production of a certain type [8]. From the perspective complementary to pathological views, the linguistic investigation demystifies both the causes and manifestations of dysarthria [9]. It has been shown that clinical treatment of dysarthria can achieve more distinct speech and better communication when treatment is complemented by the use of linguistic knowledge by directing attention to speech patterns and linguistic structures [10]. The ongoing development in linguistic dysarthria studies means that the presentation of findings on both theoretical and applied aspects is gaining increased momentum. There exists a need, therefore, for review and assessment of the present status of research into this topic. While many previous studies on dysarthria have tended to take the form of literature reviews from a traditional narrative perspective, those using scientific mapping techniques through quantitative and visual analyses remain scant.

Applications such as CiteSpace [11] and the R package Bibliometrix [12] can enable data visualization, facilitate the efficient organization of information on journals, authors, institutions, and international cooperation, and create comprehensive clustering diagrams and tables. In this respect, those software tools were used to visually analyze 1,850 linguistic research articles on dysarthria published from 1966 to 2024. This overview will sum up the status of the field, locate research hotspots, and trace development tendencies in dysarthric research in a bid to refer to the same for future studies.

2. Materials and Methods

2.1 Materials

The data materials used in this paper includes working with four processes which are: data retrieval, data cleaning, data collection and data presentation.

In the first stage, data retrieval, the bibliometric data for this study were retrieved from Web of Science (accessed on April 9, 2024), which is widely and reliably used as a library resources [13]. In the search for the term "Dysarthri*", which includes not only dysarthria and dysarthric, but also other terms inclusive or exclusive to the meaning, the term was used in a broader sense. The search was conducted in the "Topic" section of the website which covers the title, abstract, author keywords and Keywords Plus in order to make sure that all the papers are core research works dealing with dysarthria, and not mere reference in the text [14].

Cleaning of data refined the dataset further, from the initially retrieved process to ensure its recall. Documents initially retrieved were 7698 across all Web of Science categories, with the intention of capturing everything which could be potentially considered research. This was refined further down to 7069 records by limiting retrieval only to Articles, Proceedings Papers, and Review Articles, to assure that only documents that are peer-reviewed and high quality would form part of this core research in the field. It was limited to categories, such as Audiology, Speech-Language Pathology, Linguistics, Rehabilitation, Acoustics, and Language Linguistics to achieve precision. In all relevant research areas of linguistics, dating from 1966 up to 2024, a total of 1850 records have been identified. The search has been carried out on 9 April 2024 to avoid discrepancies because of daily database updates.

Following the second stage, the data collection stage focused on gathering the retrieved data in a more holistic way. Therefore, the "Full Record and Cited References," essential for Co-citation and Bibliographic Coupling Analysis, was chosen and downloaded in PlainText format by exporting the 1,850 records into four .txt files, as each export is limited to 500 records or fewer.

Finally, the bibliometric networks were created, visualized, and analyzed during the data visualization stage with the use of two software applications, namely CiteSpace (version 6.1.R6) and Bibliometrix (version R. 4.3.3).

Figure 1 represents the systematic flow of data retrieval, data cleaning, data collection, and data visualization.

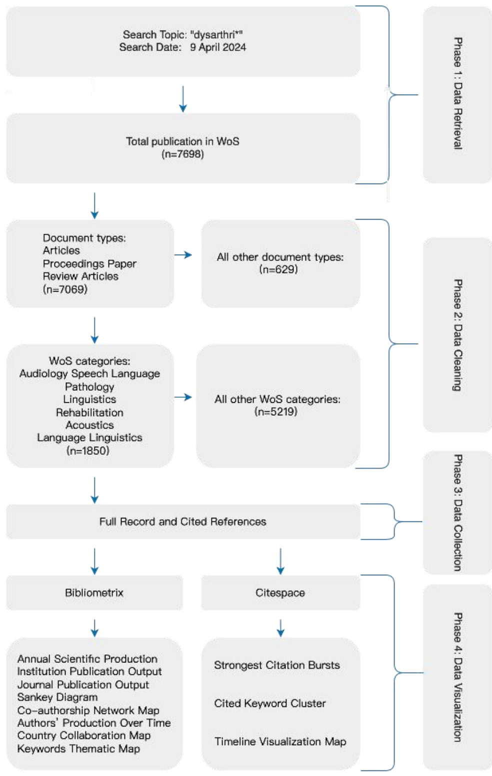

Figure 1. Systematic Flow

2.2 Methods

Bibliometric analysis describes the published research in quantitative terms-that is a visualization tool used by scholars to evaluate academic works within a particular topic. Visualization tools range from HistCite, which was developed at Drexel University in Philadelphia by Eugene Garfield and is specifically designed for the publication of citation history to identify key articles in a specific research field [15]. This present study undertakes a more holistic visualization analysis that covers aspects other than those of publications and key articles. Hence, CiteSpace and Bibliometrix were selected to be used in this study.

CiteSpace, developed by Dr. Chaomei Chen in 2004, is a Java-based tool specifically designed for knowledge visualization through co-citation analysis [16]. CiteSpace was an effective algorithm in burst detection and hence was very good at determining emerging trends [17]. Its efficient clustering and dynamic visualization features make it highly suitable for keyword cluster analysis, with the ability to map the evolution of research over time [18]. With such advantages, Strongest Citation Bursts, Cited Keyword Clusters, and Timeline Visualization Maps were analyzed in this study using CiteSpace.

Bibliometrix is an integrated package for quantitative research in bibliometrics, proposed by Aria and Cuccurullo in the year 2017. It is an R-based platform that offers versatile support, from data processing to advanced graphical visualization [19]. The seamless integration of R packages like ggplot2 into it enables flexibility and extensive, detailed visualization options for a researcher; hence, it has been a perfect choice for visualization analysis [19]. The analysis combined Bibliometrix and CiteSpace into a use that complemented the other; Bibliometrix supplemented further visualizations, such as Annual Scientific Production, Institution Publication Output, Journal Publication Output, Sankey Diagrams, Co-authorship Network Map, Authors' Production Over Time, Country Collaboration Map, and Keywords Thematic Maps.

3. Results

3.1 Descriptive Bibliometric Analysis

In Table 1, one sees that 1850 articles appeared in 170 journals, books, etc., written by 3767 authors within the period 1966–2024. Among the documents recorded in the database, 1,850 are supported by an annual growth rate of 5.21%, showing that dysarthria is a fast-developing research area, as this growth rate surpasses 5%. It also boasts an average citation rate per document of 21.98, indicating that the research achievements are widely recognized among the academic community [20]. The section for authors lists 3,767 different authors, with 105 single-authored documents. Collaboration metrics indicate that there are, on average, 3.79 co-authors per document, and that 15.08% of the works involve international co-authorships; hence, there is a clear trend toward teamwork and global partnership in research [21]. The dataset includes 1,422 articles, which are the most common type of document, 198 proceedings papers, and several other types of documents. After all, the general information outlined in Table 1 is discussed in detail in the headlines of the following study.

Table 1. Main Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1966:2024
Documents	1850
Annual Growth Rate %	5.21
Average citations per doc	21.98
AUTHORS	
Authors	3767
Authors of single-authored docs	105
AUTHORS COLLABORATION	
Co-Authors per Doc	3.79
International co-authorships %	15.08
DOCUMENT TYPES	
article	1422
proceedings paper	198
review	88
other type	142

3.2Annual Scientific Production

Figure 2 depicts the timeline of publication milestones in dysarthric research. The first article within this domain was published in 1966 by Tikofsky, R. S., Glattke, T. J., and Tikofsky, R. P., which represented the very beginning of scientific interest in dysarthria. This seminal paper "Listener Confusions in Response to Dysarthric Speech," published in Folia Phoniatrica, deals with how analysis of perceptual errors in listener responses can serve as an enlightening approach to characteristics and variability in dysarthria and thus set a trend for future research in the field. Subsequent to this pioneering study, the area has witnessed a steady output of publication activities reflective of sustained academic commitment to research into dysarthria. The growth trend falls into three stages. The three stages are from 1966 to 1990, where less than 10 articles were published each year; the embryonic phase is represented. Between 1991 and 2009, the number of papers multiplied four-fold compared to the first phase, indicating the developmental phase. In the final stage, from 2010 to 2024, the number of publications shot up terribly, indicating its blossoming. In all, publications in this area have increased yearly for the past two decades, a fact that underlines the sustained research interest in dysarthria.

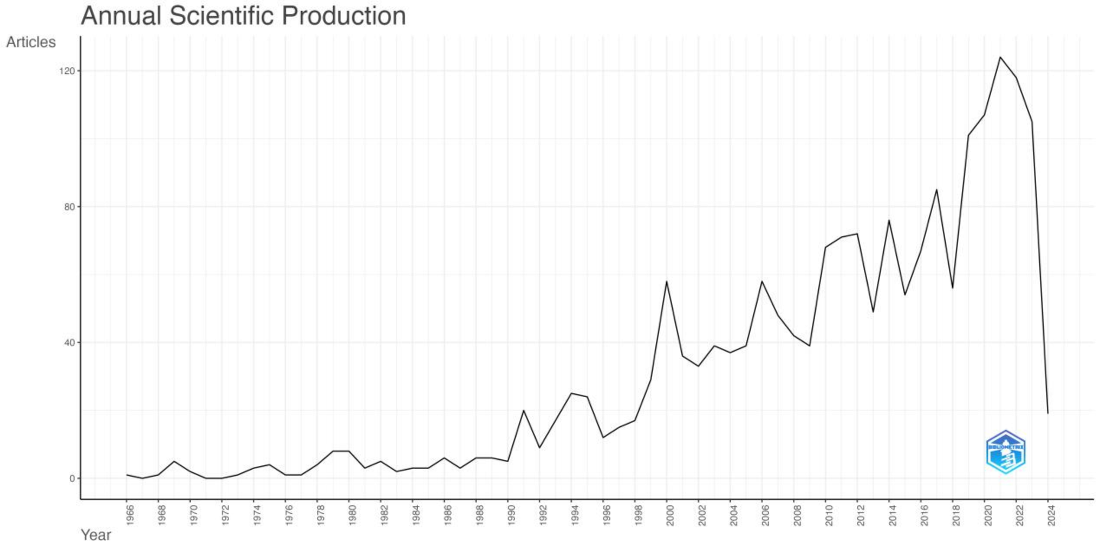

Figure 2. Dysarthria Publication Years

3.3 Collaboration and Influencers

This section presents a quantitative analysis of dysarthria literature based on the WoS database. It covers Output by Institution Publication, Journal Publication Output, Influential Authors, National cooperation, and Highly Cited References falling within the scope of the concerned research area.

3.3.1 Institution publication output

The table 2 below documents the top 10 institutions with the highest output. Data are highly concentrated to research emerging from universities mainly located in North America and Australia. The University of Wisconsin-Madison has the leading position, contributing 168 articles alone, which outnumbers that of other institutions, proving that it plays the most major role in dysarthria research. The table indicates slight variation in publication number among the second to fourth ranks: University of Wisconsin System with 97 articles, University of Toronto with 92, and University of Washington-Seattle with 87 articles, indicating quite intensive competition in dysarthria research between the universities. Of the top 10 most prolific institutions, ranked by number of publications produced, the University of Toronto and the University of Queensland represent the only two representatives of Canada and Australia, respectively, while the remaining eight institutions represent the United States, demonstrating the leading position that the U.S. has taken in dysarthria research.

3.3.2 Journal publication output

The higher the amount of articles and citations a journal has published, the more influential the journal is considered to be [22]. For this reason, the analysis calculated the number of articles, the total citations received, and the H-index associated with journal citations. The H-index attempts to reach a balance between the amount of articles published and the quality of the impact, measured by the number of citations received [23]. Table 3 ranks the top 10 most productive journals in the field, in descending order, with respect to their contribution to the number of articles published.

Table 2. Top 10-most Productive Institutions by the Number of Publications

Ranks	Affiliation	Articles
1	UNIVERSITY OF WISCONSIN MADISON	243

2	UNIVERSITY OF WISCONSIN SYSTEM	97
3	UNIVERSITY OF TORONTO	92
4	UNIVERSITY OF WASHINGTON SEATTLE	87
5	UNIVERSITY OF QUEENSLAND	78
6	UNIVERSITY OF WISCONSIN SYSTEM	75
7	MAYO CLINIC	64
8	ARIZONA STATE UNIVERSITY-TEMPE	63
9	STATE UNIVERSITY OF NEW YORK (SUNY) BUFFALO	60
10	STATE UNIVERSITY SYSTEM OF FLORIDA	48

A total of 1,422 articles produced over the period 1966–2024 have been published in 170 different journals. The Journal of Speech, Language, and Hearing Research ranks first with 236 articles, primarily published by the American Speech-Language-Hearing Association (ASHA) in the United States, and boasts the highest number of total citations at 4,802 and an H-index of 47, which is considered high, as well-regarded academic journals in niche fields typically have an H-index in the 30-50 range [23]. The range of total citations and H-index values across journals indicates varying degrees of influence and scientific impact within the field, with the Journal of Speech, Language, and Hearing Research leading in both total citations and H-index, underscoring its profound influence in dysarthria research. The table shows a mixture of publishers from the United States and United Kingdom, with one from Switzerland. Notably, most journals are from the United States, except for Clinical Linguistics & Phonetics from the United Kingdom and Folia Phoniatrica et Logopaedica from Switzerland. These numbers indicate the dominance of the United States. The ranks of publications and citations in the list tend to differ. For instance, the Journal of Communication Disorders, which ranks third by the number of citations, ranks 7th in terms of the number of articles. Journal of Medical Speech-Language Pathology, which ranks 6th by the number of citations, ranks second with 145 articles.

The Sankey Diagram indicating the relationships among keywords (left), authors (middle), and journals (right) is three-dimensionally illustrated in Figure 3. The figure describes the authors' contribution to the relevant journals and their keyword preferences. According to the Sankey Diagram, the higher the number of links among the variables, the thicker the connection lines. Katherine C. Hustad, the most prolific author in this field, specializes in communication development in children with cerebral palsy (CP). Keywords such as "intelligibility," "cerebral palsy," and "acoustic analysis" are more prominently linked in her research, indicating a deeper and more substantial impact in these areas. She has published extensively in leading journals, including *the Journal of Speech Language and Hearing Research*, *Journal of Medical Speech-Language Pathology*, *Clinical Linguistics & Phonetics*, *Folia Phoniatrica et Logopaedica*, and *American Journal of Speech-Language Pathology*. The strong connections between her work and these journals highlight her core contributions to the field. Moreover, Raymond D. Kent, who ranks second in productivity, has focused on the keywords "dysarthria," "intelligibility," and "Parkinson's disease" in his contributions to *the Journal of Speech Language*, *Journal of Medical Speech-Language Pathology*, and *American Journal of Speech-Language Pathology*. His research primarily investigates infant vocalizations, speech development, motor speech disorders, and acoustic analyses of speech. Currently, he is exploring developmental functional modules in infant vocalizations and motor processes in both typical and disordered speech. The relationships between authors, keywords, and journals in the Sankey Diagram provide a foundational understanding of the research landscape. Moving forward, the co-authorship network (Figure 4) further reveals how these influential authors connect and collaborate, adding another layer of insight into the field's development.

Table 3. Top 10-most Productive Journals by the Number of Publications.

Ranks	Journals	Articles	Publishers	Countries/Regions	Total citations	H-index
1	JOURNAL OF SPEECH	236	American	United States	4802	47

	LANGUAGE AND HEARING RESEARCH		Speech-Language-Hearing Association (ASHA)			
2	JOURNAL OF MEDICAL SPEECH-LANGUAGE PATHOLOGY	145	Delmar Learning	United States	1405	23
3	CLINICAL LINGUISTICS & PHONETICS	137	Informa Healthcare	United Kingdom	1742	32
4	AMERICAN JOURNAL OF SPEECH-LANGUAGE PATHOLOGY	109	American Speech-Language-Hearing Association (ASHA)	United States	1471	26
5	FOLIA PHONIATRICA ET LOGOPAEDICA	91	S. Karger AG	Switzerland	1438	28
6	INTERNATIONAL JOURNAL OF LANGUAGE & COMMUNICATION DISORDERS	85	Wiley-Blackwell	United States	806	24
7	JOURNAL OF COMMUNICATION DISORDERS	83	Elsevier Inc.	United States	1696	30
8	INTERNATIONAL JOURNAL OF SPEECH-LANGUAGE PATHOLOGY	67	Informa Healthcare	United Kingdom	515	19
9	JOURNAL OF VOICE	46	Mosby Inc.	United States	940	19
10	BRAIN AND LANGUAGE	42	Academic Press Inc.	United States	1318	24

R *—Ranks, J *—Journals, P *—Publishers, CR *—Countries/Regions, TA *—Total articles, TC *—Total citations, and 1: https://www.scimagojr.com/journalrank.php (accessed on 20 December 2022)

3.3.3 Influential authors

Co-authorship is used, most often, for the study of collaborations between authors in published articles Figure 4. If two authors co-author an article, a link will be created between them in a co-authorship network [24].This type of network is particularly useful for researchers searching for potential collaborators or for publishers assembling editorial teams [25].

The co-authorship analysis has selected 48 most strongly linked authors out of 3,767, and these authors have been divided into nine distinct clusters. Kent Ray D. and Hustad K. C. are tied in the ranking for the number of links: Kent is at the central node of the 7th cluster in pink and Hustad at the central node of the 1st cluster in red, underlining their roles within the collaboration networks they are part of. Raymond D. Kent is a well-known faculty member at the University of Wisconsin-Madison, while Katherine C. Hustad is also affiliated with the same university and significantly with the Waisman Center. Their areas of interest have already been mentioned in the Sankey diagram. Kathryn M Yorkston holds the central node of the fifth cluster (orange) and second rank in the overall network. We can notice from the co-authorship network map that the highly productive scholars are less interactive with other researchers, leading to a very sparse collaboration network. It means that in dysarthria research, much more attention has to be turned to facilitating co-operation among the highly productive scholars.

Table 4 presents the first 10 top authors who have produced the largest number of publications among the 3767 authors. By observing Table 4, Bruce E. Murdoch from the University of Queensland is ranked first with 57 research articles on the topic. As a co-author, Murdoch has contributed to an important paper entitled "Consensus Paper: Language and the

Cerebellum: An Ongoing Enigma," published in *The Cerebellum*. This has proven to be his most cited scholarly publication, as it showed that parts of the cerebellum are involved in learning, cognition, and language-in contrast to the traditional view of the cerebellum as being primarily a motor control structure [26]. Not far behind is RD Kent from the United States with 46 articles, affiliated to the University of Wisconsin - Madison, the same university associated with the third-ranked KC Hustad and the ninth-ranked G Weismer, indicating a centre of considerable research activity. W Ziegler, in fourth place with 42 articles, is the only German contributor on this list, from the EKN Clinical Neuropsychology Research Group.

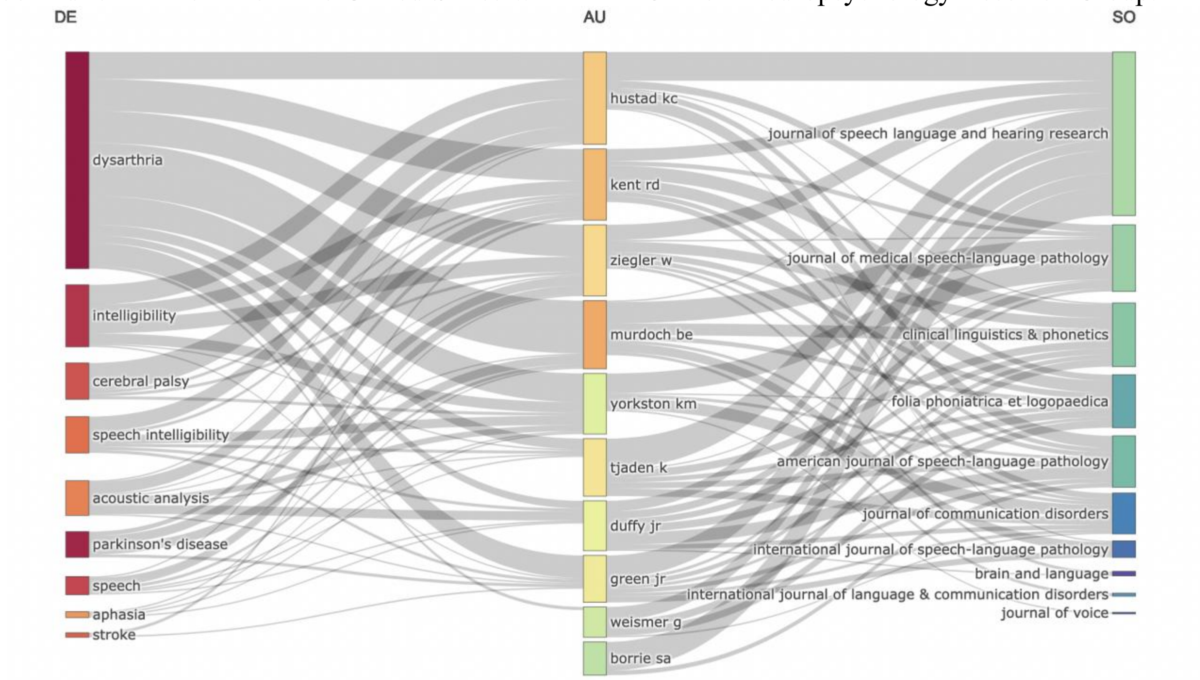

Figure 3. Sankey Diagram of Author, Journal, and Keywords

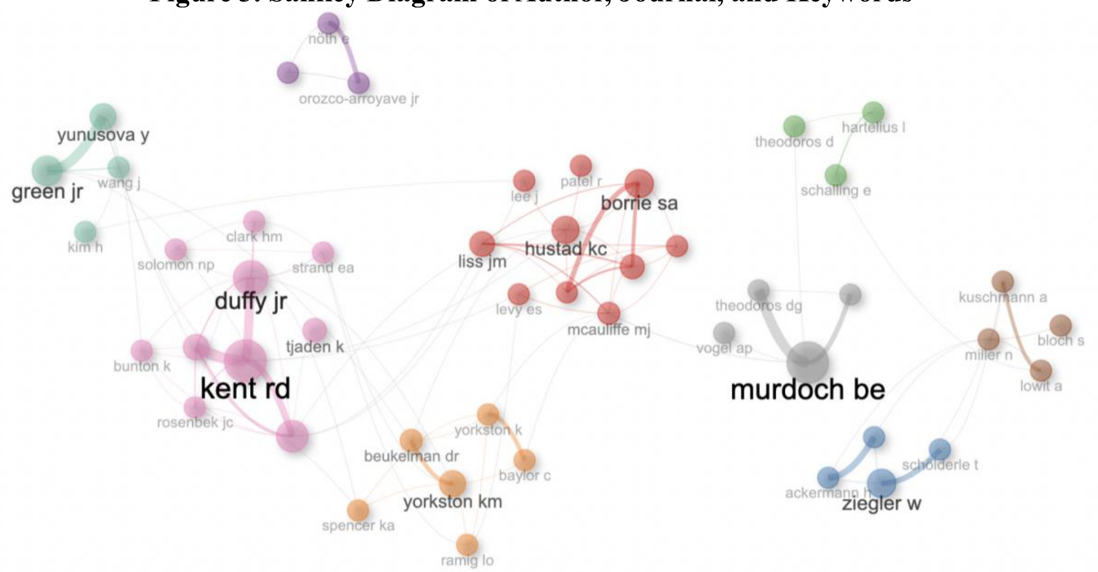

Figure 4. Co-Authorship Network Map

Table 4. Top 10-Most Productive Authors

Ranks	Authors	Articles	Country	Institution
1	MURDOCH BE	57	Australia	University of Queensland
2	KENT RD	46	United States	University of Wisconsin - Madison
3	HUSTAD KC	44	United States	University of Wisconsin - Madison
4	ZIEGLER W	42	German	EKN Clinical Neuropsychology Research Group
5	TJADEN K	41	United States	University at Buffalo

6	GREEN JR	40	United States	MGH Institute of Health Professions
7	DUFFY JR	38	United States	Mayo Clinic in Rochester, Minnesota
8	YORKSTON KM	36	United States	University of Washington
9	WEISMER G	34	United States	University of Wisconsin - Madison
10	BORRIE SA	31	United States	Utah State University

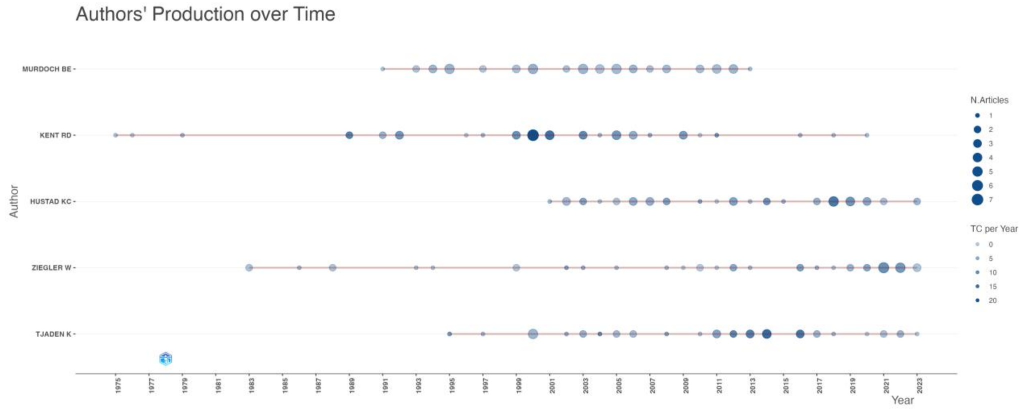

Figure 5. Production of Top Authors over time. TC = Total Citation

In quantitative analyses of academic output, the Authors' Productivity Over Time (Figure 5) provides a straightforward option for exploring and evaluating publication productivity and citation impact for the time period selected. This chart visualizes scholarly activities in terms of color intensity and size of the dots, where the horizontal axis is for time, in years, and the vertical one lists the researchers. In fact, the size of the dot depends on the number of papers which a scholar publishes in any given year; hence, straight away the years in which output was prolific can easily be identified. The greater the number of publications in any one year, the larger the dot. Also, the color depth or grayscale level of the dots presents the citation count for each paper per year- the total citations per year, TC per year- where darker dots denote articles that received a higher citation count. For example, the outstanding performance by Professor Kent RD was realized in the year 2000, where 7 of his articles were published that particular year and is averaging 20.52 citations.

3.3.4 National cooperation

The Table 5 lists top 10 most productive countries. When countries are ranked by publication count, the three most productive countries are USA (783), the UK (151), and Australia (125), respectively. For the USA, the number of SCP is far more than that of MCP, 699 and 84 respectively. This trend, in which SCP is significantly higher than MCP, can also be seen in other countries. The MCP_Ratio for Canada, China, and Belgium was as high as 0.25, 0.221, and 0.278, respectively.

Table 5. Top 10-Most Influential Countries

Ranks	Country	Articles	SCP	MCP	Freq	MCP_Ratio
1	USA	783	699	84	0.423	0.107
2	UNITED KINGDOM	151	127	24	0.082	0.159
3	AUSTRALIA	125	112	13	0.068	0.104
4	GERMANY	86	75	11	0.046	0.128
5	CANADA	84	63	21	0.045	0.25
6	CHINA	68	53	15	0.037	0.221
7	SWEDEN	50	43	7	0.027	0.14
8	FRANCE	46	37	9	0.025	0.196
9	NETHERLANDS	37	30	7	0.02	0.189
10	BELGIUM	36	26	10	0.019	0.278

SCP- Single Country Publications, Freq- Frequency (Articles/Publication), MCP- Multiple Country Publications, and MCP_Ratio- MCP/ Articles.

Figure 6 may be conducive to understanding a country's capacity and exploring capacity differences among various countries in terms of research distribution at a country or region level [27]. Academic collaboration among different countries or regions may assume the role of guiding the promotion of knowledge dissemination and academic exchange [28]. The following world map depicts the country-based affiliation of authors in the collaboration. Light colors in the map represent weak relationships while darker colors indicate stronger ones. Grey colour indicates no connexion. In Figure 6, the Method Parameters the "Min edges" is to set to 2, that means the line showing the connection between two countries is displayed only in case the number of the collaborations between them reaches or is larger than two. This parameter sets the minimum threshold above which edges are displayed on the map. In the Graphical Parameters, "Edge size" is set to 5, which means the line will be moderately thick. The "Edge size" parameter sets the thickness of the connection lines. The higher the number, the thicker the line.

Analysis of intercountry links shows that USA and Canada have the largest number of strongest links with 53 each. Accordingly, the second and third positions are taken by the USA's links with New Zealand and China, correspondingly having 21 and 19 links. Distinct regional features of international cooperation also appear in the "Countries' Collaboration World Map". First of all, there is a prominent link between North America and Asia: the map denotes the large number of times the United States collaborates with many Asian countries, especially China. The second fact is that a complex web of partnerships within Europe points towards a high integration in research collaborations, arguably because of proximity and comparative similarity in research and educational systems. Thirdly, Australia acts as an important hub in international cooperation, connecting very strongly across Asia and into North America in the Pacific region. Whereas South America works with Europe, its interactions with North America and Asia are relatively much less dense.

3.3.5 Highly cited references

Table 6 provides the titles of articles with the highest citations, titles of related articles, authors, DOI numbers, year of publications and number of citations in general. The first pioneer work, which was cited 858 times, was done by DARLEY FL in the year 1969 and was published in *the Journal of Speech and Hearing Research*. The present research was focused on the various diagnostic patterns of dysarthria related to neurological disorders and specified the kind of speech and voice changes in every condition. The subjects tackled by these articles vary, including diagnostic patterns of dysarthria, phonetic intelligibility testing, speech and swallowing symptoms, and speech studies covering specific diseases like Parkinson's disease and multiple sclerosis.

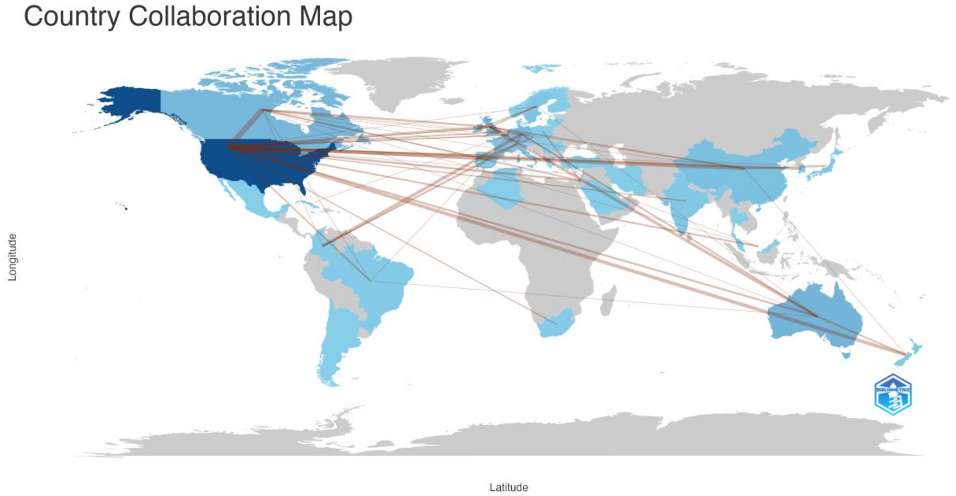

Figure 6. Country Collaboration Map

Table 6. Top 10–Most Cited Papers

Ranks	Paper	Year	Journals	Title	DOI	Total Citations
1	DARLEY FL	1969	Journal of Speech and Hearing Research	Differential diagnostic patterns of dysarthria	10.1044/jshr.1202.246	858
2	DARLEY FL	1969	Journal of Speech and	Clusters of deviant speech dimensions	10.1044/jshr.	513

			Hearing Research	in the dysarthrias	1203.462	
3	KENT RD	1989	Journal of Speech and Hearing Disorders	Toward phonetic intelligibility testing in dysarthria	10.1044/jshd.5404.482	342
4	HARTELIUS L	1994	Folia Phoniatrica et Logopaedica	Speech and swallowing symptoms associated with Parkinson's disease and multiple sclerosis: a survey	10.1159/000266286	285
5	DANIELS SK	1998	Archives of Physical Medicine and Rehabilitation	Aspiration in patients with acute stroke	10.1016/S0003-9993(98)90200-3	283
6	MARIEN P	2001	Brain and Language	The lateralized linguistic cerebellum: a review and a new hypothesis	10.1006/brln.2001.2569	250
7	WEISMER G	2001	Folia Phoniatrica et Logopaedica	Acoustic and intelligibility characteristics of sentence production in neurogenic speech disorders	10.1159/000052649	241
8	SAPIR S	2007	Journal of Speech, Language, and Hearing Research	Effects of Intensive Voice Treatment on Vowel Articulation in Dysarthric Individuals With Idiopathic Parkinson Disease: Acoustic and Perceptual Findings	10.1044/1092-4388(2007/064)	236
9	TURNER GS	1995	Journal of Speech and Hearing Research	The influence of speaking rate on vowel space and speech intelligibility for individuals with amyotrophic lateral sclerosis	10.1044/jshr.3805.1001	229
10	SAPIR S	2010	Journal of Speech, Language, and Hearing Research	Formant Centralization Ratio: A Proposal for a New Acoustic Measure of Dysarthric Speech	10.1044/1092-4388(2009/08-0184)	222

3.4 Keywords

3.4.1 Keywords thematic map

Scientific mapping techniques include thematic maps showing the conceptual structure of a specific research domain (Figure 7). Thematic Map includes network analysis for word occurrences to explain what science is saying in a field, key themes, and patterns [29]. It also uses density as an indication of consistency between nodes, while centrality is an indication of relevance degree of various subjects. Thematic maps can be typified into four main types: Basic Themes, Motor Themes, Niche Themes, and Emerging or Declining Themes.

Figure 7 below shows the themes "dysarthria," "speech," and "intelligibility" enclosed in the blue circle. These are the Basic Themes. This place suggests that the themes are basic, central in the research of the area, highly relevant, and relatively mature, hence the focal point for the researchers. The themes that fall within the orange circle, "individuals," "Parkinson's disease," and "speaking rate," cut across the boundary between Motor and Basic Themes. These topics are of high relevance and reflect highly developed areas of recent research, either emerging or well-established trends in the last few years. Located in the red circle, themes such as "perception," "recognition," and "dysarthric speech" are classified as Niche Themes; this would tend to suggest that while these topics are very well developed, their relevance is not as marked as those in either the Basic or Motor Themes, which may indicate that they represent specialized research areas or emerging technologies. Finally, themes such as "aphasia," "people," and "quality of life" that emerged in the purple circle are categorized as either Emerging or Declining Themes. These themes may just be at their nascent stages or may be gradually rejected under the present corpus; the level of relevance and development remains low.

3.4.2 Citation bursts

The frequency of keyword occurrence in a period can be judged using KeyWord burst analysis. In this way, it will help find the trending hotspots of research directions. This way, it will discover areas where research might be carried out on dysarthria and predict the future research trends of the topic [30]. Figure 8 was obtained by using the CiteSpace tool in publications listed in the Web of Science database based on keyword burst analysis. The result of the analysis is discussed below.

It follows that according to the WOS database, the most bursty keyword is "amyotrophic lateral sclerosis" with a strength of 12.28, starting in 1994 until 2008. It is followed by "traumatic brain injury" with a strength of 11.23, keeping the burst period between 2000 and 2011. Other single keywords with high burst strengths are "classification" at 11.01. Bursts of early keywords are indicative of research trends: "amyotrophic lateral sclerosis" from 1994 to 2008, "deficits" from 1994 to 2005, "duration" from 1994 to 2011, and "speech" from 1994 to 1999. Recent hotspots, such as "classification" starting in 2015, and "speech recognition" and "bulbar" starting in 2018, point out these areas as having been of interest recently. The burst persistence for "bulbar" lasts until 2024, reflecting the interest in that research area that has been sustained. These continuous bursts of the keywords relate to an ever-growing trend within the respective research fields and have very great potential in the future studies.

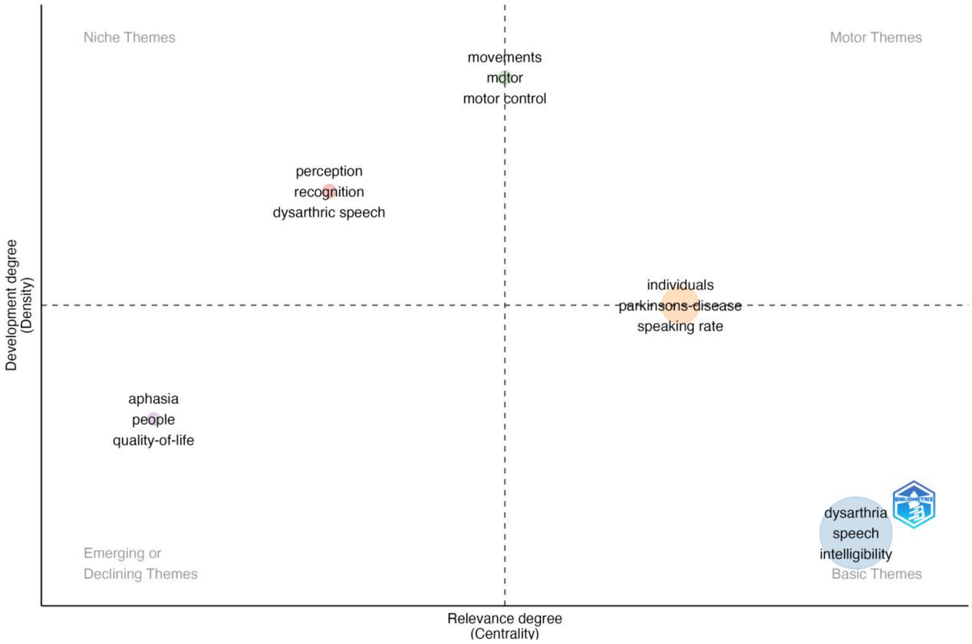

Figure 7. Keywords Thematic Map

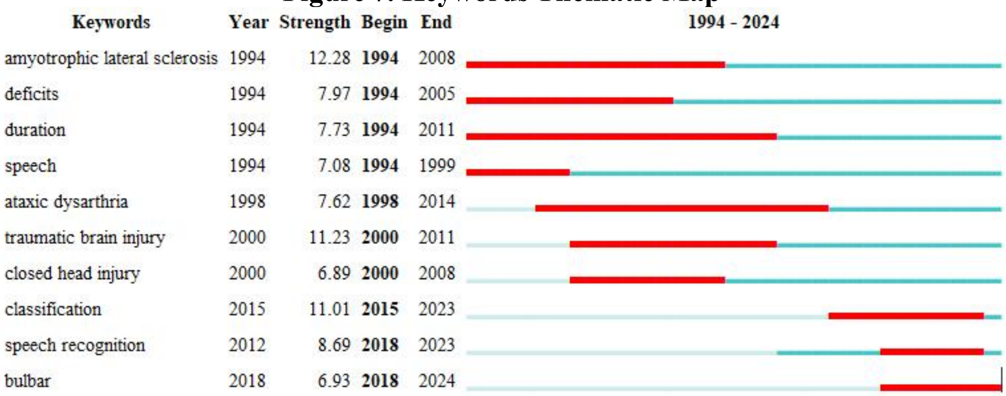

Figure 8. Top 10 Keywords with the Strongest Citation Bursts

3.4.3 Keyword clustering

Using the CiteSpace software, a co-citation analysis (Figure 9) was performed on the dysarthria literature from the WOS database, resulting in several effective clusters. First, the associated literature and research themes for each cluster were identified by analyzing the clustering information and keyword nodes in CiteSpace. Then, the natural clusters from CiteSpace were integrated into keyword clusters based on thematic relationships. Finally, the software-generated clusters were categorized into four major research directions: Types of Dysarthria, Speech Characteristics of Dysarthria, Rehabilitation for Dysarthria, and Technology for Dysarthria. The following sections provide a detailed analysis of the four major research directions and their associated cluster groups.

3.4.3.1 Types of dysarthria

Dysarthria in the WOS database, represented by the types of Cluster #2 classification, Cluster #5 amyotrophic lateral sclerosis, and Cluster #11 deglutition, respectively. There are some highly frequent keywords like speech motor delay, Parkinson disease, cerebral palsy, deglutition disorders, and dysphagia are under these three main categories.

In Cluster #2 classification, scholars mainly focus on the classification of dysarthria severity. For example, Joshy et al. use the multi-head attention mechanism (MeHA) in conjunction with a multi-task learning approach to explore aeutomated dysarthria severity level classification [31]. Cluster #5 is primarily focused on motor speech disorders, which in many instances are related to neurological impairments. A classic example is the work of Ying Qian Ong and Jaehoon Lee, who investigate the effects of Parkinson's disease on oral-diadochokinesis rates in Malaysian-Malay speakers [32]. Cluster 11 is more related to deglutition. For example, Camila Dalbosco Gadenz et al. performed a systematic review of randomized controlled trials regarding the effects of rTMS on rehabilitation aspects related to communication and deglutition disorders [33].

3.4.3.2 Speech characteristics of dysarthria

Cluster #0 multiple sclerosis, Cluster #3 movement, Cluster #6 speech motor control, and Cluster #7 speech talk of dysarthria's speech characteristics as its main focuses on the WOS database. Cluster #0 deals only with the acoustic characteristics of multiple sclerosis, temporally, spectrally, and phonatorily comparing persons with MS to healthy controls. The latter were researchers Lena Hartelius and colleagues [34]. The movement of Cluster #3 is most directly concerned with the relationship of jaw movement to speech intelligibility. For example, Yana Yunusova et al. reported that in three cases of bulbar ALS, increased movement duration was associated with a decline in speech intelligibility over the course of the disease [35]. Cluster #6 primarily concentrate on the speech motor control. For example, Deling He described speech rates of Mandarin speakers with PD and the associated articulation and pause characteristics [36].

3.4.3.3 Rehabilitation for dysarthria

Cluster #4 is WOS communication, Cluster #9 is communicative participation, Cluster #10 impairment, Cluster #13 is the speaker, and Cluster #14 is deep brain stimulation, which mainly show the direction of dysarthria rehabilitation. In Cluster #4 classification, scholars mainly focus on the parameters of communication in both therapy and rehabilitation. For example, Vera Wolfrum considers the speech aspects of the parameters of communication and he discovers that dysarthric speech rating by speech-language therapists is influenced by both adaptation benefits and therapeutic biases [37]. Cluster #9 looks into the rehabilitation of the language function and also the communicative competence. For instance, Betts Peters found that aided communication can enable PALS to continue participating in a variety of situations requiring communication as the speech function declines [38]. Cluster #10 is about the rehabilitational judgment in people with neurological impairment. For example, Ismail Safaz found that Patients with traumatic brain injury are seen to face a wide spectrum of complications and these complications are deeply related to cognitive function. In the rehabilitation of these patients with TBI, they should be promptly followed up by a multidisciplinary team [39]. Dysarthria rehabilitation nowadays focuses mostly on speech functionality improvement and enhancement of communicative competence, while psychological aspects have not been highlighted yet. A complex treatment of dysarthria from the psychological and linguistic standpoints favorably influences speech clarity and emotional stability. Therefore, in the future, rehabilitation should be directed toward the incorporation of psychological interventions regarding the comprehensiveness of the multidisciplinary approach for patients.

3.4.3.4 Technology for dysarthria

In the WOS database, Cluster #1 individual, Cluster #8 speech recognition and Cluster #12 speech movement all basically focus on the technology of dysarthria. In Cluster #1 individual, scholars mainly focus on the application of emerging technology in the individual assessment and therapy of patients with speech disorders, especially in automatic speech processing. For example Imed Laaridh et al. established that an automatic speech processing system is powerful in identifying dysarthric speech anomalies. This process is more objective and fine-grained than human examiners regarding the analysis of small speech units [40]. Cluster #8 discusses the speech recognition technology as a pivotal technology in dysarthria area. For instance, Erfan Loweimi investigated that multi-stream acoustic modeling using the raw real and imaginary parts of the Fourier transform of speech signals achieved competitive performances in speech recognition tasks [41]. Cluster 12 focuses on the perception and expression in supplemental speech such as iconic gesture and alphabet supplementation. This is supported by Deniz Jafari, who identified that kinematic features from 3D video recordings of simple clinical tasks bear clinical validity and are related to perceptual clinical orofacial ratings in individuals with neurological disorders [42].

3.4.4 Timeline analysis

Figure 10 depicts the visual highlighting of the temporal relationships in the keyword network related to the dysarthria area. Years are represented along the horizontal axis of the cluster timeline view and the cluster labels are represented along the vertical axis. The two circles are closer, the more closely the two keywords collaborate. The vertical organization of the clusters is based on the cluster size in descending order, meaning the biggest cluster is always located at the top within the view [43]. Since it has the highest number of citations, a large node represents high research interest in the area of dysarthria. Since the number started from zero was used for clustering, Cluster 0 is the largest and Cluster 1 is the second largest. As can be seen from the timeline overview, cluster 0, cluster 10, and cluster 12 all have a duration of more than 30 years. In Cluster 0, words such as "acoustic characteristics" and "vowel acoustics" allow seeing that through this long period there was an interest in acoustic characteristics of multiple sclerosis. It has shown particular activity in recent years and reflects continued interest and development in the research area covered by.

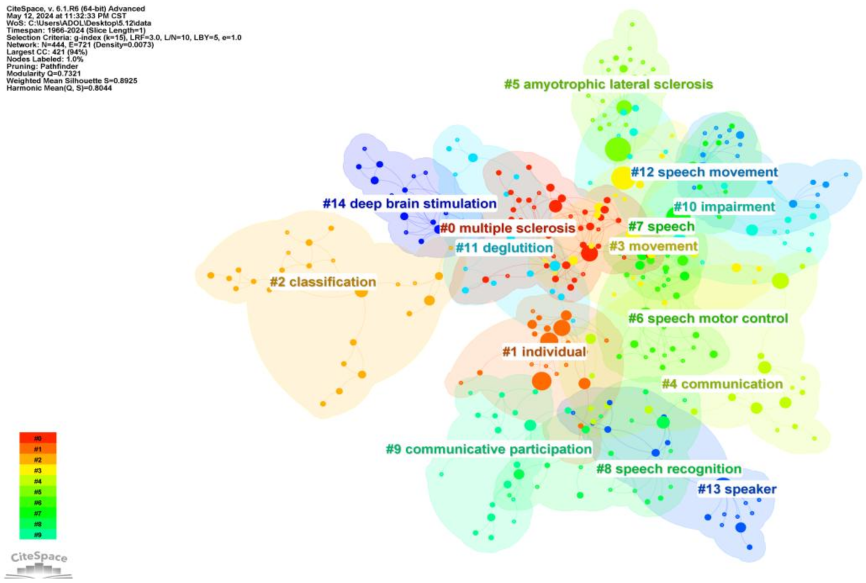

Figure 9. Keyword Clustering

Cluster 1 seems to focus on elements of dysarthria research that are more individualistic, either in the case of specific cases or personalized treatment strategies. Keywords of recent times such as "speaking rate" and "children" tend to reveal a general trend that has come out of research into individual characteristics.

The keywords in Cluster 2 include "speech motor delay", "4-year-old children", and "language". It reflects the trend of main classification direction on the type of dysarthria, namely clinical characteristics, age of onset, and language development. This cluster represents a continuous trend from the end of the last century to recent years, reflecting increasingly specialized and changing methods of categorization of dysarthria.

These three keywords, "bulbar", "tongue", and "intelligibility", therefore indicate that this cluster 3 deals with the articulatory and physiological aspects of speech production. Research in this area has been relatively consistent, focusing on understanding the physical factors affecting speech.

Cluster 4 incorporates keywords such as "communication", "quality of life", and "telepractice", emphasizing a focus on dysarthria's social and functional impacts on daily living.

In the field of dysarthria, there is increasing attention to the keywords "vowel acoustics," "deep learning," and such are very relevant up to date.

4. Conclusions

4.1 Development

Research on dysarthria is an important part of speech pathology. Dysarthria is a relatively young branch that came into being in 1966 in academic research. Within almost 70 years, it has developed at a very fast pace, with 1,850 articles published in 170 journals. From the annual output perspective, it's possible to roughly identify three stages: the embryonic stage, the development phase, and the blossom period. That's to say, Dysarthria research has been developing from exploration to maturity and therefore shows bright prospects for the future.

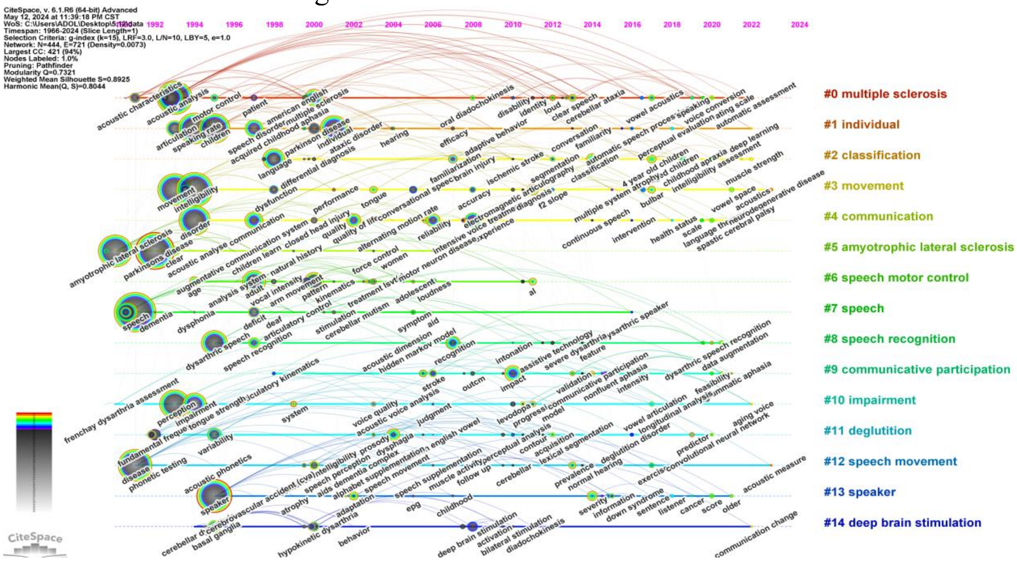

Figure 10. Timeline View of Keyword Clustering Map

4.2 Distribution

From the geographical distribution point of view, the most productive institutions in general are those located in Europe and America, which is also reflected in the publication of articles. Thus, *the Journal of Speech, Language and Hearing Research* of the United States is highly productive, which reveals the great importance of dysarthria as part of the academic context of the USA. Besides, the top ten most influential authors are from the USA, Australia, and Europe, and Murdoch Be tops the list. From the geographical distribution, it can be developed that dysarthria research is mainly concentrated in the developed countries where academic resources and research environments are advantageous.

4.3 Collaboration

The international co-authorship of this field totals 15.08 percent of the overall number of papers, which reflects a sound trend in the field of dysarthria study. However, the share of SCPs is greater than that of MCPs, so far indicating that a network of international cooperation in dysarthria research is not yet fully developed. The USA and Canada maintain close cooperation, likely due to geographical proximity. Another important aspect that current research suggests that interactions and collaborations between many highly productive authors are limited, resulting in a relatively sparse overall collaboration network.

4.4 Keyword Clustering

Keyword clustering analysis identified the type of dysarthria, speech characteristics, rehabilitation strategy, and technology application as four major research directions. These directions indicated not only that research was broadly conducted in this field but also the direction of future development. Although substantial research has been conducted on the types of dysarthria and the speech characteristics associated with each, few studies integrate psychological aspects into the rehabilitation of dysarthria, especially among children. More emphasis will be needed in the future on the combination of psychological support with increased social adaptability to achieve more inclusive therapeutic gains. Recent developments in technologies such as deep learning and speech recognition also has massive potential regarding enhancing diagnostic precision and rehabilitation strategies. A comprehensive approach that includes speech therapy, psychological support, and high technology will make the lives and social integrations of dysarthric people stronger.

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