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Original Article

Systematic Review on Technological Devices for the Communication of Hearing-impaired Children from 2002 to 2023

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Abstract - *Currently, the World Health Organization reports that more than 430 million people worldwide have hearing impairment, with a projection of 900 million by 2050. In particular, approximately 35 million children worldwide are affected by this condition. Early cortical auditory development plays a crucial role in a child's life, and any deficiency in auditory function during these formative years can hinder proper synaptic development. This systematic review aims to explore the landscape of technological devices designed to improve communication for children with hearing disabilities. This study analyzed existing literature through rigorous methodology, employing bibliometric network analysis to uncover key insights and utilizing the Scopus database in conjunction with Vosviewer and Visual Basic Applications. As a result, 8,827 scientific documents were obtained, wherein authors, countries, affiliations, document types, publication years, and keywords were analyzed. Articles constituted the majority of these documents, comprising over 64.1%, and the peak in document production occurred in 2022 with 620 documents. In conclusion, the development of technological devices has yielded significant results over the last 20 years, incorporating recent trends such as machine learning and artificial intelligence for creating new devices. However, there was limited consideration for children or the caregivers and family members of individuals with hearing disabilities.*

Keywords - *Systematic review, Deaf, Child, Device.*

1. Introduction

Hearing impairment is the total or partial loss of auditory sense in one or both ears [1]. It significantly impacts an infant's development in various aspects of life, including language development, education, autonomy, and socialization [2]. Currently, the World Health Organization (WHO) reports that more than 430 million people suffer from this type of disability [3], and it is projected to visibly increase to 900 million people with hearing impairments by the year 2050 [4]. Furthermore, approximately 35 million children worldwide are affected by this disability [5]. The development of the auditory cortex in the early years of a person's life is crucial; when auditory capacity does not function properly at a young age, it fails to stimulate adequate synaptic connections [6]. Hearing impairment or loss is considered when there is a pure-tone average exceeding 20 decibels per ear [7], as categorized in [8] into levels such as mild, moderate, severe, and profound, with ranges of 26-40 dB, 41-60 dB, 61-80 dB, and 81-< dB, respectively. This disability can occur due to various factors, including congenital factors observed during the neonatal period, late-onset attributed to etiologies that manifest after birth [9], acquired when not present at birth [10], neurosensory hearing loss caused by cochlear injury [11], and conductive hearing loss involving damage to the external or middle ear [12].

An early intervention through cochlear implantation helps infants improve their auditory senses [13]. It is recommended to use this type of intervention in those with neurosensory hearing loss, as it can recover more than 70% of the auditory sense. However, this solution comes at a high cost, exceeding 42,000.00 Peruvian soles per unit [15], and many people cannot access it due to economic issues and the clinical limitations of various healthcare centers [16].

In 2016, the Social Health Insurance of Peru (EsSalud) invested over 5,400,000.00 Peruvian soles to purchase 126 cochlear implant units to allow new deaf-born children to regain their hearing [15]. Technological advancements and the development of new devices are benefiting children with hearing disabilities. In [17], the lack of medical attention in Canada for patients with hearing disabilities is mentioned. As a proposed solution, portable audiometry is used as a means of early diagnosis for low-income populations.

The study involved 218 elementary school children from Northern Canada, using tablet audiometers. As a result, the test duration was within six minutes, and it was concluded that 14.8% of the studied population tested positive for hearing loss using the audiometer. Due to the time-saving nature of this diagnostic method, it is highly beneficial for rural and remote communities with limited access to such diagnostics. Technological evolution has led to the production of devices for communication facilitation in deaf children and immediate detection methods for diagnosis. Therefore 2005, as mentioned in [18], a new treatment for children with congenital bilateral auditory atresia called BAHA Softband was introduced. The objective was to evaluate the validity of the bone-anchored hearing aid (BAHA) attached to the softband. The methodology involved two children with hearing loss aged 3 years and 28 months who had a transcutaneous BAHA softband applied. The 28-month-old child received this type of hearing aid, and after 5 months of unilateral use, this type of device could be inserted bilaterally. Using artificial mastoids, the performance of this new application, combining BAHA Classic and Compact as sound processors and audio, was evaluated. The results included a comparison with an Oticon E 300 P, a bone-conduction device. To validate the BAHA softband, speech development, and electroacoustic measurements were evaluated, showing minor differences among the three mentioned devices. Additionally, volume modulation allowed for better device stabilization compared to Classic and the device. In conclusion, the Softband successfully intervened in children with congenital bilateral auditory atresia who were too young for percutaneous BAHA application.

On the other hand, efforts have been made to find effective and cost-effective solutions to enhance the communication of children with hearing disabilities. In [19], it is noted that cochlear implants are expensive, and many children cannot access them. Recent technological advances have provided cost-effective solutions that are non-invasive and do not require surgical intervention. These solutions involve compact haptic actuators that offer intense stimulation at multiple frequencies. The objective is to create a non-invasive, low-cost device resembling audio frequency bands that convert into vibrations. This study involved 26 participants with normal tactile abilities and aimed to discriminate tactile phonemes using one, four, or eight frequency bands. The performance showed 5.9% accuracy for four frequency bands and 8.4% for eight frequency bands. Due to its compact size, the device can be implemented as a low-cost haptic hearing aid, and its vibrations can be reproduced through low-power actuators. Furthermore, the new technological era of audio and Wi-Fi has led to development of low-cost technological solutions for communities facing socioeconomic challenges. In [20], a user-friendly and affordable Android smartphone is used to construct a unidirectional communication system that sends text messages from a family member to a hearing-impaired patient. This technology involves two devices: a smartphone and a smartwatch (models ST18i, Android version 4.0.4, SONY, and MN2, SONY, respectively). Two different software types were used, one developed by the research group and the other from CustomNotifierExtension, utilizing Bluetooth 3.0 for communication. The system sends text messages, either via voice or keyboard input, and requires pressing the send button. When the message is received, the child feels a vibration from the smartwatch.

The study evaluated the coverage range in a wooden two-story house and a concrete building. The results showed a coverage range of 10 meters, with a transmission delay of less than 1 second. Reception remained reliable on both floors of the wooden house and in the apartment of the concrete building, with disconnection occurring only when the person was in a corner of a room. In conclusion, this unidirectional communication system has been designed primarily for successful low-cost communication interventions.

Similarly, noteworthy developments of low-cost and accessible devices for low-income communities aim to facilitate communication for children with hearing disabilities. In 2019, as described in previous study, a research group in Peru developed a device for alerting children with hearing disabilities to potential risks at a cost of less than $100. The device is designed to recognize audio recorded as alerts or messages of assistance sent by a close family member to the child with hearing impairment.

This device consists of a transmitter and a receiver that communicate via wifi 802.11 within a range of up to 95 meters, using cost-effective components such as WeMos D1 mini Lite boards. The technology was tested on a group of 20 caregivers of hearing-impaired children, resulting in a 74% approval rate out of 100%. The primary mode of communication for these caregivers was sign language. In conclusion, this device represents a technological solution alternative for economically disadvantaged children with hearing impairments, opening the door to further research in the realm of inclusion and improved quality of life.

This research aims to conduct a systematic review to determine the reality of technological support devices for the community of children with hearing disabilities to enhance communication for the child and their environment. The methodology for gathering necessary information regarding technologies created to improve communication quality for children will be presented. After obtaining the document quantity, the main results will be analyzed. The Vosviewer software tool will automatically analyze these results to present bibliometric network graphics. The information obtained will be compared with previous research. Finally, conclusions and recommendations will be proposed to inspire new investigations in this healthcare field, benefiting not only children but also adults.

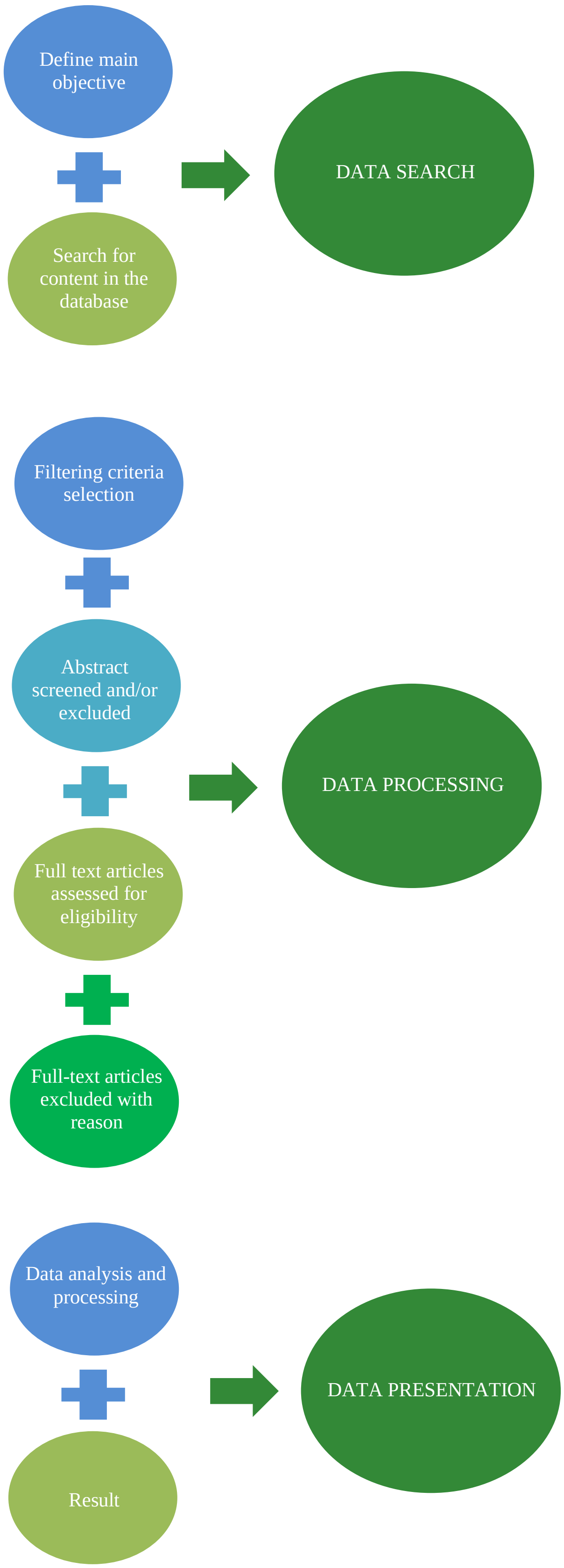

Fig. 1 Hybrid Flowchart

2. Methodology

2.1. Flowchart

The flowchart is a diagram based on symbols with lines that serve to connect and display the step-by-step of each procedure [21]. This diagram provides a clear view of the details of each process and helps to understand more quickly which tasks will be carried out during the research [22]. Thanks to this tool used in the methodology it allows for a more detailed overview of what will be done in the systematic review of electronic devices that aid in the communication of children with hearing impairment, as shown in Fig. 1. In Figure 1, three important stages are depicted, which are divided according to the procedures to be carried out in the research. The first process is data search, which includes two subprocesses: defining the primary objective and conducting an intensive search of content in the Scopus and PubMed databases [23].

The second process is data processing, consisting of five sub-processes. These include applying selection criteria filtering [24], followed by data exclusion. Next is the eligibility subprocess, which involves data exclusion based on specific criteria and reasons [25]. The final process involves data presentation, where all the data gathered in the second process are analyzed and processed, culminating in the presentation of results at the end of this stage [26].

2.2. PRISMA

The PRISMA systematic review is the methodology used in the research based on a literature review to determine how many assistive devices for deaf children exist through a search using Boolean terms [27]. The purpose of PRISMA is to synthesize the current state of the presented research [28]. This systematic review methodology, depicted in diagrams, offers four phases to facilitate obtaining the results [29]. These four phases are called identification, screening, eligibility, and inclusion [30]. In phase 1, where information is identified, a database is used, thanks to logical operators like AND, OR, and AND NOT, which aid in searching research articles [31]. In the following screening phase, there is a filter for including and excluding information [32]. Phase 3 involves a second review to resolve any discrepancies [33]. The final phase deals with the analysis of the results [34].

2.3. Data Search

In this process, we work on data retrieval by filtering desired information using Boolean operators in Scopus [35]. That is why this research is based on an intensive bibliometric review of assistive devices for deaf children.As mentioned earlier, Boolean operators, with the content of these search scripts, allow us to obtain the desired information [36]. One of these operators is OR; in [37], it is mentioned that this operator aids in combining information. In contrast, AND, as explained in [38], requires both the first and second conditions or the specified words to result in a true response, displaying information based on the input.

Let us not forget that AND NOT assist in the search by excluding terms that are not needed in the information [39]. Furthermore, we appreciate the variety of documents offered by Scopus, including articles, reviews, letters, conference papers, notes, and more, from which we will select those containing valuable information related to our research objective.

2.4. Data Processing

After collecting data from the previous process, we will now proceed to analyze all the gathered information [40]. This opens the way for the inclusion and exclusion criteria for information from the Scopus database, focusing only on document types such as reviews, scientific articles, conference papers, and books [41], as they provide the necessary information for this research [42]. Thanks to this process, we can enter a critical stage, ensuring validation in the systematic review [43].To carry out this analysis process, we must consider using Boolean algorithms through logical operators to broaden the search [44]. However, we may also rely on human intervention to add certain important documents, such as letters, book chapters, or unclassified ones, which contribute positively to achieving the proposed objective. All the collected information is processed using the free software VOSviewer, which will assist us in bibliometric analysis represented in networks based on nodes and links [45]. VOSviewer: is software that aids researchers in conducting bibliometric reviews [46] based on authorship and reference data processing [47]. This tool is represented by nodes, which represent elements such as authors, keywords, and others, while the links represent relationships [48]. Thanks to this software, we can identify patterns and trends in the current research [49]. On the other hand, remember that Scopus provides a classification of Open Access documents displayed in a table along with the number of documents in the repository, allowing us to know how many records we can access.

2.5. Data Presentation

Thanks to VOSviewer, bibliometric networks or maps were generated, represented by nodes and links, showing authors of publications grouped in clusters [50]. Additionally, a heatmap is also displayed with keywords, showing the intensity of colors in the graph and reflecting their frequency of appearance in the abstracts [51]. On the other hand, bar charts will show the distribution of publications by year [52]. Furthermore, the assistance of Visual Basic Applications was required to customize graphics [14].

3. Results

Conducting a systematic review of assistive devices for children with hearing loss allows for identifying the best possible solutions and how effective and guaranteed access to technology can be for deaf children. Indeed, the evaluation of a systematic review opens up a list of options to choose from regarding the best decision for the child's communication with their caregiver and vice versa. It also aims to promote future innovative research and investments in new developments that benefit this community.

3.1. Data Search

During this process, an intensive data search was conducted to collect the necessary information regarding the objective, using a bibliometric review of assistive devices for children with hearing loss. Furthermore, let us remember the importance of the selection criteria mentioned in the methodology regarding devices for deaf children, their components, and their existing technological representations, excluding implants and invasive procedures.

Next, the following algorithm retrieved from the Scopus database is presented for the selection criteria:

(TITLE-ABS-KEY (deaf) AND TITLE-ABS-KEY (device) OR TITLE-ABS-KEY (gps) OR TITLE-ABS-KEY (ergonomic) OR TITLE-ABS-KEY (receivers) OR TITLE-ABS-KEY (battery) OR TITLE-ABS-KEY (sd) OR TITLE-ABS-KEY (led) OR TITLE-ABS-KEY (oled) OR TITLE-ABS-KEY (protocol) OR TITLE-ABS-KEY (low AND cost) OR TITLE-ABS-KEY (wifi) OR TITLE-ABS-KEY (bluetooth) OR TITLE-ABS-KEY (wireless) OR TITLE-ABS-KEY (bidirectional) OR TITLE-ABS-KEY (tutor) OR TITLE-ABS-KEY (wereable) OR TITLE-ABS-KEY (recognition) OR TITLE-ABS-KEY (hearing) OR TITLE-ABS-KEY (communication) OR TITLE-ABS-KEY (impariment) OR TITLE-ABS-KEY (mobile) OR TITLE-ABS-KEY (haptic) OR TITLE-ABS-KEY (transmit) OR TITLE-ABS-KEY (watch) OR TITLE-ABS-KEY (bracelet) OR TITLE-ABS-KEY (vibrotactile) OR TITLE-ABS-KEY (electrotactile) OR TITLE-ABS-KEY (tactile) OR TITLE-ABS-KEY (tactual) OR TITLE-ABS-KEY (touch) OR TITLE-ABS-KEY (vibration) OR TITLE-ABS-KEY (interface) OR TITLE-ABS-KEY (feedback) OR TITLE-ABS-KEY (display) OR TITLE-ABS-KEY (technology) OR TITLE-ABS-KEY (vibration AND device) OR TITLE-ABS-KEY (translation) OR TITLE-ABS-KEY (braile) OR TITLE-ABS-KEY (protocol) OR TITLE-ABS-KEY (language) OR TITLE-ABS-KEY (speech) OR TITLE-ABS-KEY (development) OR TITLE-ABS-KEY (visual AND gesture) OR TITLE-ABS-KEY (camera) OR TITLE-ABS-KEY (iot) OR TITLE-ABS-KEY (recognition AND system) OR TITLE-ABS-KEY (vocally) OR TITLE-ABS-KEY (smart AND band) OR TITLE-ABS-KEY (prototype) OR TITLE-ABS-KEY (motion AND capture) OR TITLE-ABS-KEY (deafblindness) OR TITLE-ABS-KEY (realtime) OR TITLE-ABS-KEY (assistive AND device) OR TITLE-ABS-KEY (smart AND watch) OR TITLE-ABS-KEY (raspberry) OR TITLE-ABS-KEY (arduino) OR TITLE-ABS-KEY (esp32) OR TITLE-ABS-KEY (atmega) OR TITLE-ABS-KEY (language AND interpreter) OR TITLE-ABS-KEY (real AND time) OR TITLE-ABS-KEY (glove) OR TITLE-ABS-KEY (helping) OR TITLE-ABS-

KEY (radar) OR TITLE-ABS-KEY (sensor) AND NOT TITLE-ABS-KEY (implant) AND NOT TITLE-ABS-KEY (invasive) AND NOT TITLE-ABS-KEY (surgery) AND NOT TITLE-ABS-KEY (review) OR TITLE-ABS-KEY (deep AND learning) OR TITLE-ABS-KEY (cnn) OR TITLE-ABS-KEY (random AND forest) OR TITLE-ABS-KEY (machine AND learning) OR TITLE-ABS-KEY (control) OR TITLE-ABS-KEY (bayes) OR TITLE-ABS-KEY (fuzzy) OR TITLE-ABS-KEY (learning) OR TITLE-ABS-KEY (supervised) OR TITLE-ABS-KEY (automata) OR TITLE-ABS-KEY (automatic))

According to the previous search algorithm, TITLE-ABS-KEY ("deaf") AND TITLE-ABS-KEY ("device"), these terms have been the main and mandatory ones for our research process. On the other hand, the other terms containing the OR connector are unnecessary for the search to return those terms since they are only supplementary. Thanks to Scopus, the research and data search could be conducted by adding the previously mentioned algorithm.

It is noteworthy that a Boolean search in this repository is relevant for obtaining information. It allowed us to refine the search using connectors like AND and OR, ensuring control over the search by specifying the terms used in our script. The initial search with the mandatory terms yielded only 10,181 documents.

3.2. Data Processing

This data processing stage is characterized by screening information, including and excluding data according to our search objective for devices that aid communication for the deaf child community. In Fig. 2, we can observe the ranking of each threshold, which shows only the top 10 journals based on citation index metrics such as CiteScore, SJR, and SNIP DATA, which match bibliographically due to the search algorithm. Furthermore, in Fig. 2, we can deduce that the information analysis was taken into account from 2002 to the present. Over the years, the American Annals of The Deaf journal prevails with more than 10 documents until it experiences a surge in the year 2022 with over 25 documents. In the current year, we observe that among all journals, the Journal of Deaf Studies and Dead Education maintains more than 15 publications about devices to assist people with deafness. After applying a second date range filter from 2002 to 2023, since we noticed in the initial filter that there were very few documents published from 1818 to 2002, and they did not provide relevant information for the research, we obtained 8,827 documents. For this new dataset, an extension of Scopus was used, thanks to Python scripts, to facilitate graphs related to authors, the number of published documents, publications by countries, and the percentage of publications by thematic area. It is worth noting that we will also analyze clusters with the help of VOS viewer, thanks to Scopus, which provided a CSV file after the last search filter was applied.

3.3. Data Presentation

For this process, we worked with 8,827 documents. Thanks to the Scopus API and VOSviewer, we could visualize the data. Figure 3 shows a historical line graph that groups all the research documents from 2002 to 2023. From what we observe, we can deduce a significant growth in research production regarding communication devices for children with hearing impairment in 2022, with 620 research papers. However, for 2023, we cannot ascertain whether there was a decrease in new research, as we only have data available up to September.

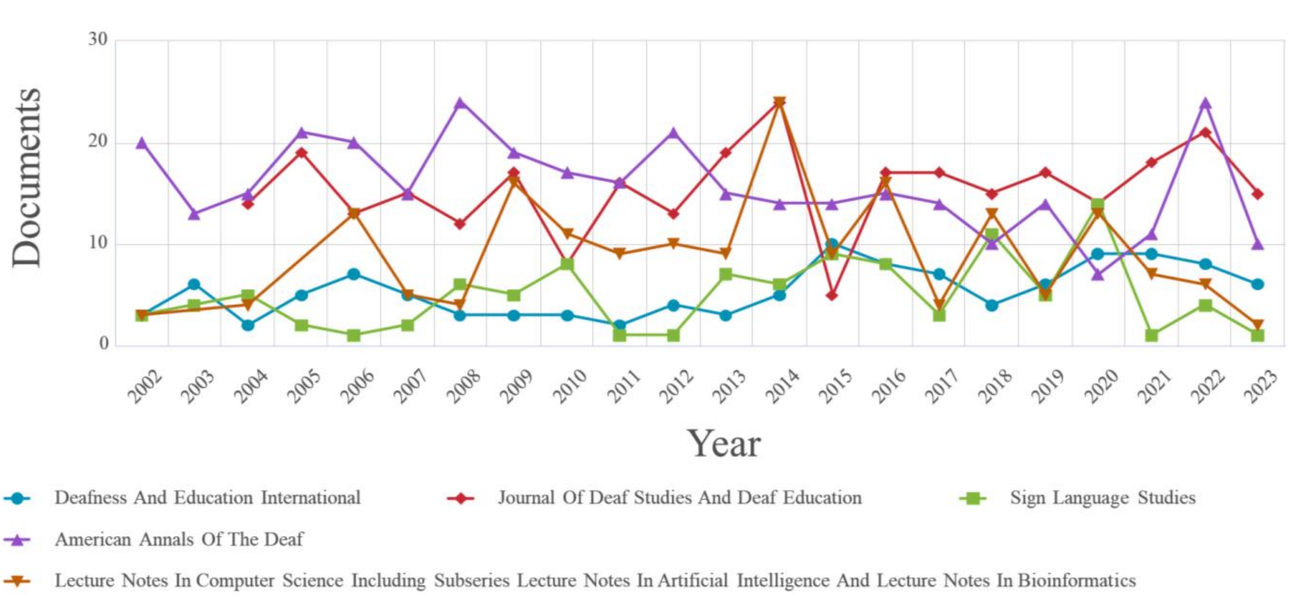

Fig. 2 Top 10 sources – Documents per year by source

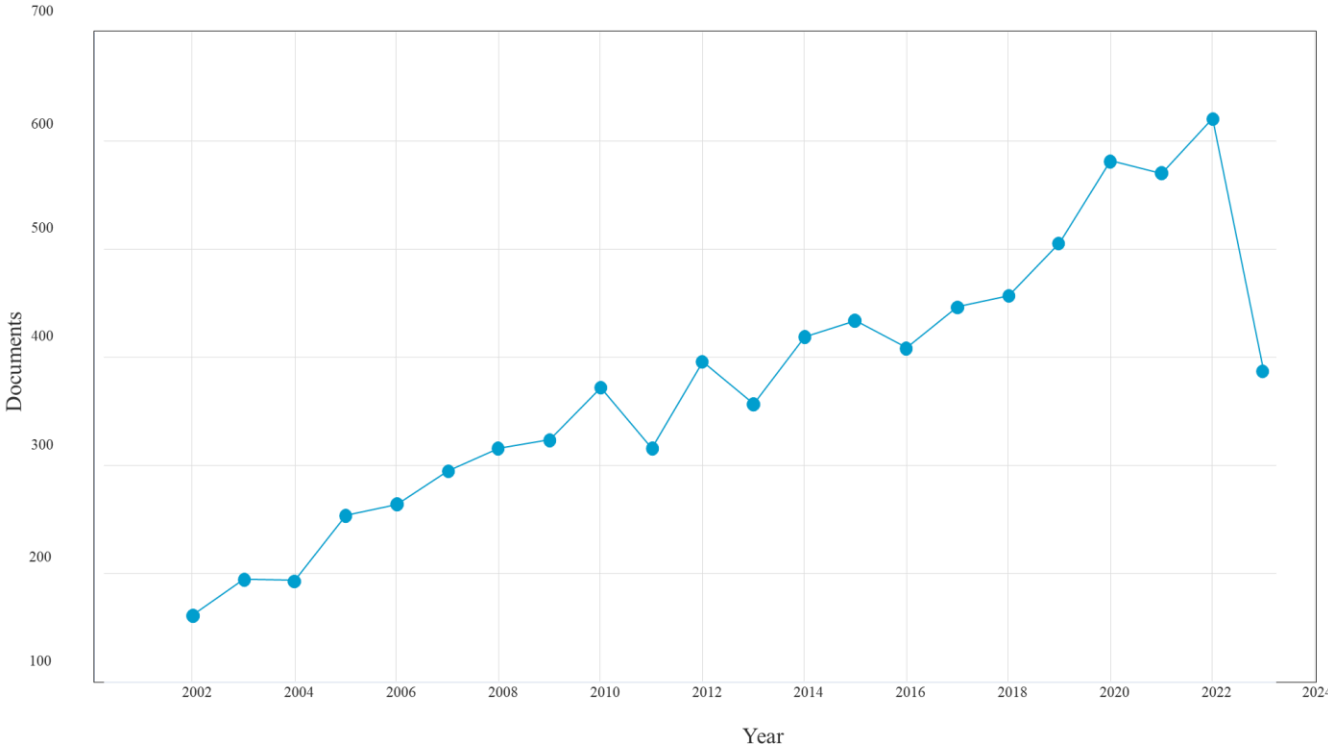

Fig. 3 Documents by year

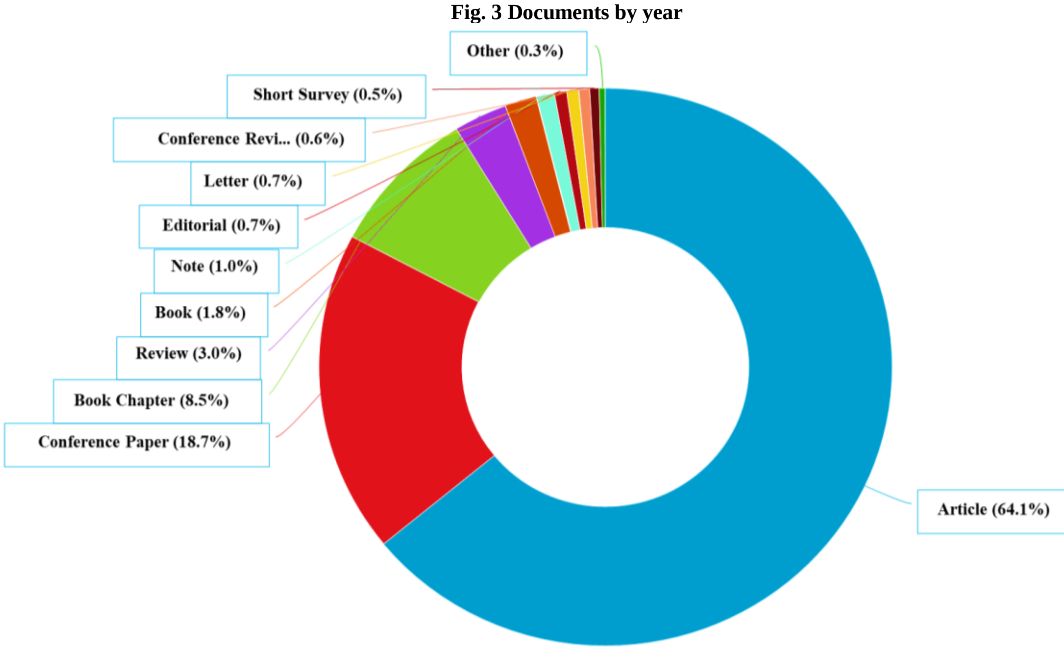

Fig. 4 Documents by type

On the other hand, in Figure 4, we see a pie chart displaying the percentages of each document type. Out of the 8,827 documents, the most significant percentage corresponds to articles, accounting for 64.1%, which would be 5,290 articles. Another significant percentage is for conference papers, at 18.7%, with 1,543 documents. However, there are percentages of less than 10% for book chapter publications, reviews, books, notes, editorials, letters, and others.

On the other hand, thanks to the affiliations, we can infer that institutions are investing in new research on assistive devices for the hearing-impaired community. Therefore, in Figure 5 of the entire research, a top 15 list of entities committed to research on the previously mentioned topic was compiled. Gallaudet University - USA has 341 published documents, followed by Rochester Institute of Technology - USA with 240 published documents, and the National

Technical Institute for the Deaf - USA with 135 published documents. The ones mentioned above are the most prominent numbers of documents. We can infer that the USA is investing in and prioritizing new technological developments to support and assist children with hearing impairment. In Figure 6, you can observe the substantial publications made by the United States, with 2,648 documents from 2002 to 2023. Following that, you can see the United Kingdom, with 812 documents published in the mentioned year range, and China, with 398 documents on assistive devices. It is known that these three countries, particularly emphasizing the United States, have a greater interest in publications regarding new technological developments. Additionally, their economic capacity for investment is well rewarded, highlighting their well-equipped laboratories for developing these devices.

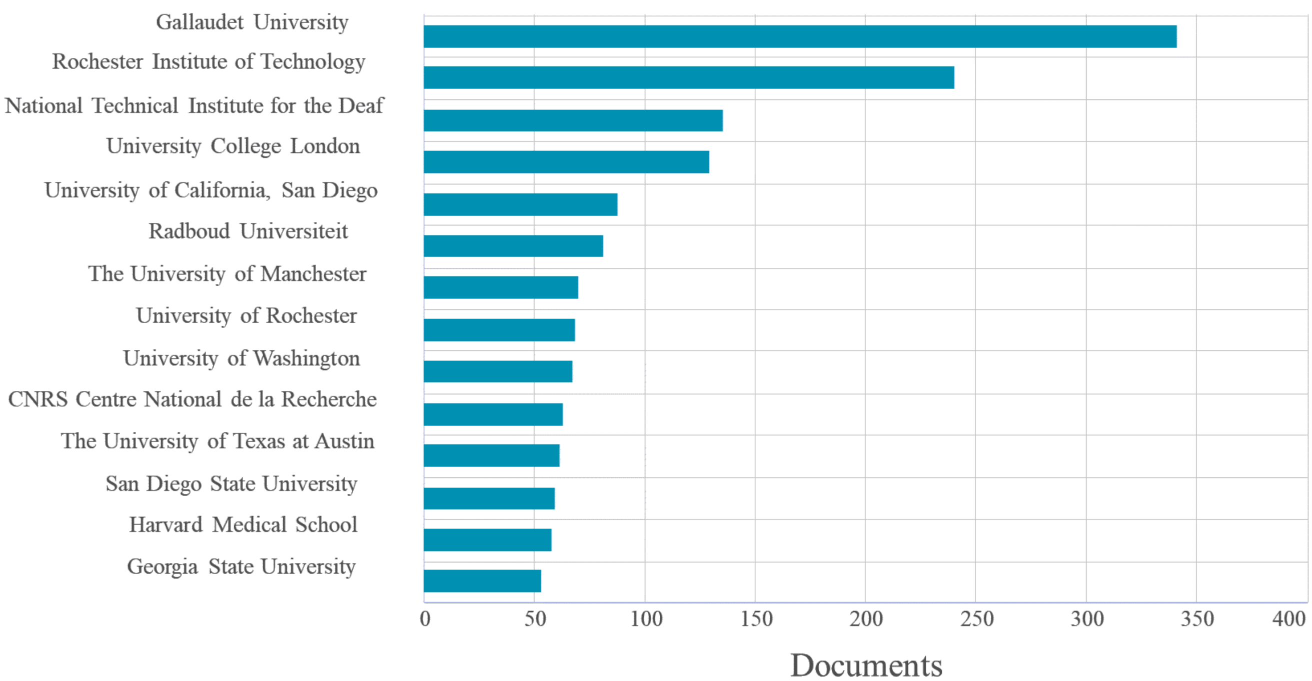

Fig. 5 Documents by affiliation

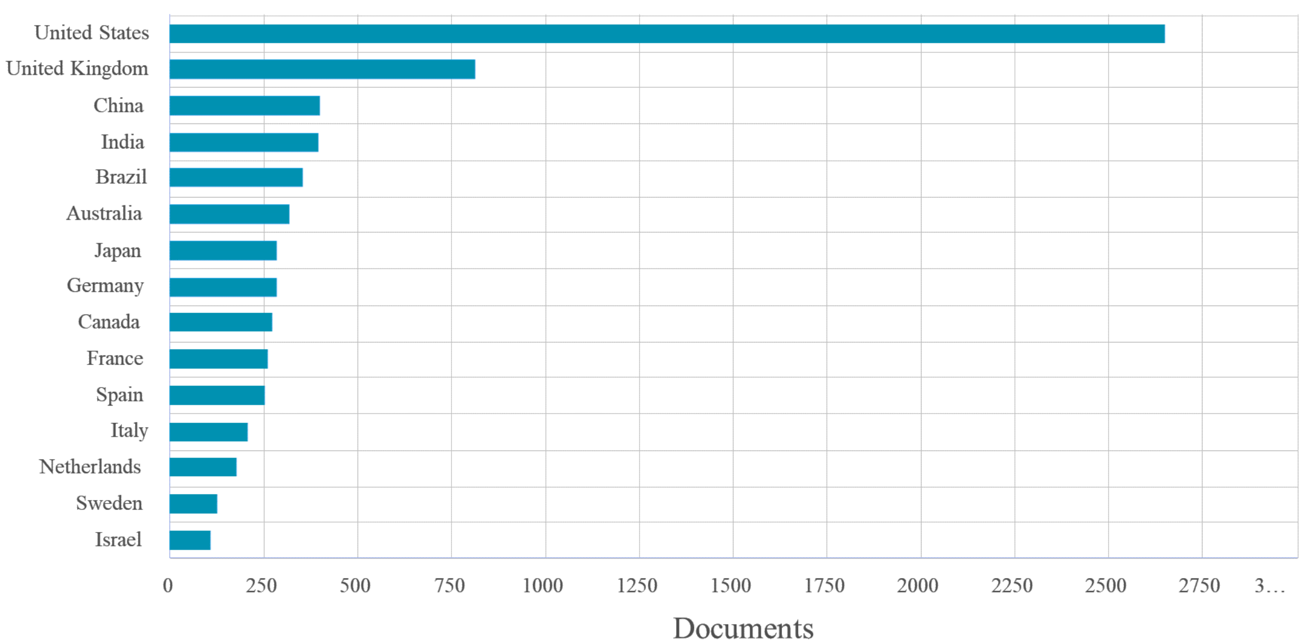

Fig. 6 Documents by country

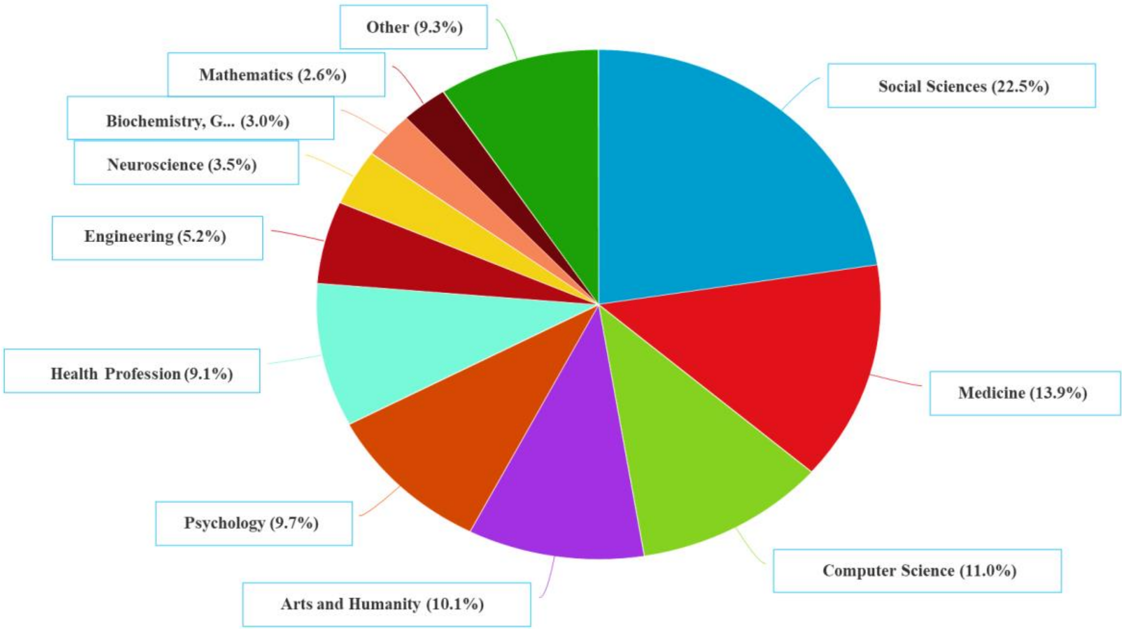

Fig. 7 Documents by subject area

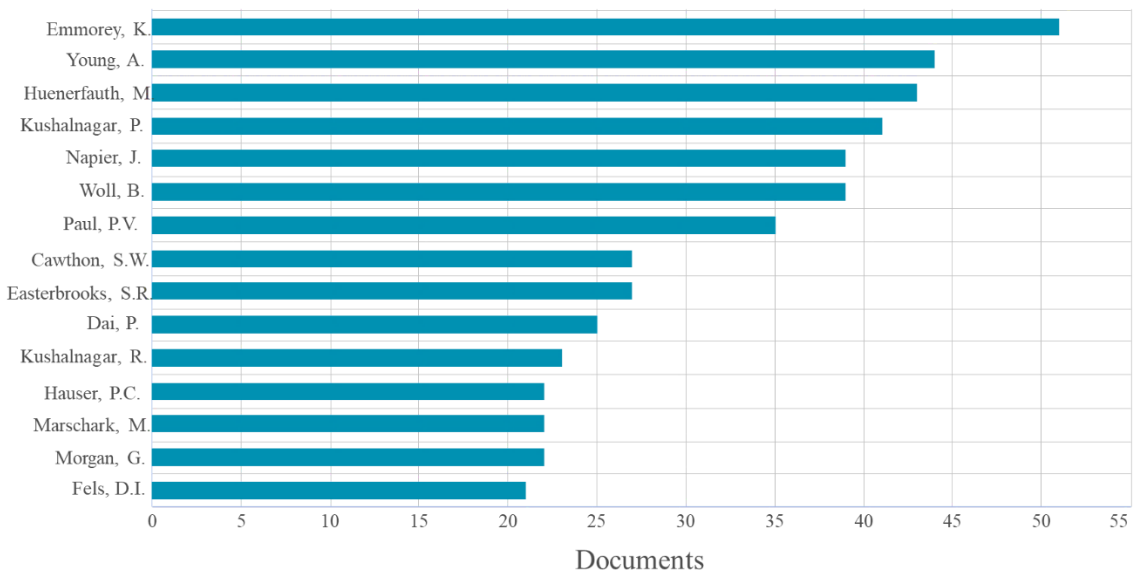

Fig. 8 Documents by author

Also, Figure 7 represents the areas that publish the most scientific documents regarding assistive devices for children with hearing loss. An area with an impactful percentage is Social Sciences, with 22.5%, covering 3,279 documents of the total collected. In second place, medicine represents 13.9% with 2,022 published documents, and Computer Science contributes 11%, corresponding to 1,604 documents.

Other fields, such as Arts and Humanities, Psychology, Neuroscience, Biochemistry, and Mathematics, fall below 10%, with fewer than 1,400 published documents. Surprisingly, Engineering only has 759 documents on developing devices that assist in communication for the child community with hearing loss. This serves as an alert to the engineering sector to increase the number of publications on this topic.

In the bar chart provided in Figure 8, we can see the top 15 authors with the most publications from 2002 to the present day. Emmorey, K. has 51 publications related to these devices. Young, A., Huenerfauth, M., and Kushalnagar, P. have 44, 43, and 41 publications, respectively. It can be inferred that this chart correlates closely with Figure 6, which shows the countries with the highest publications. In other words, these authors are from the United States, with a higher proportion of publications.

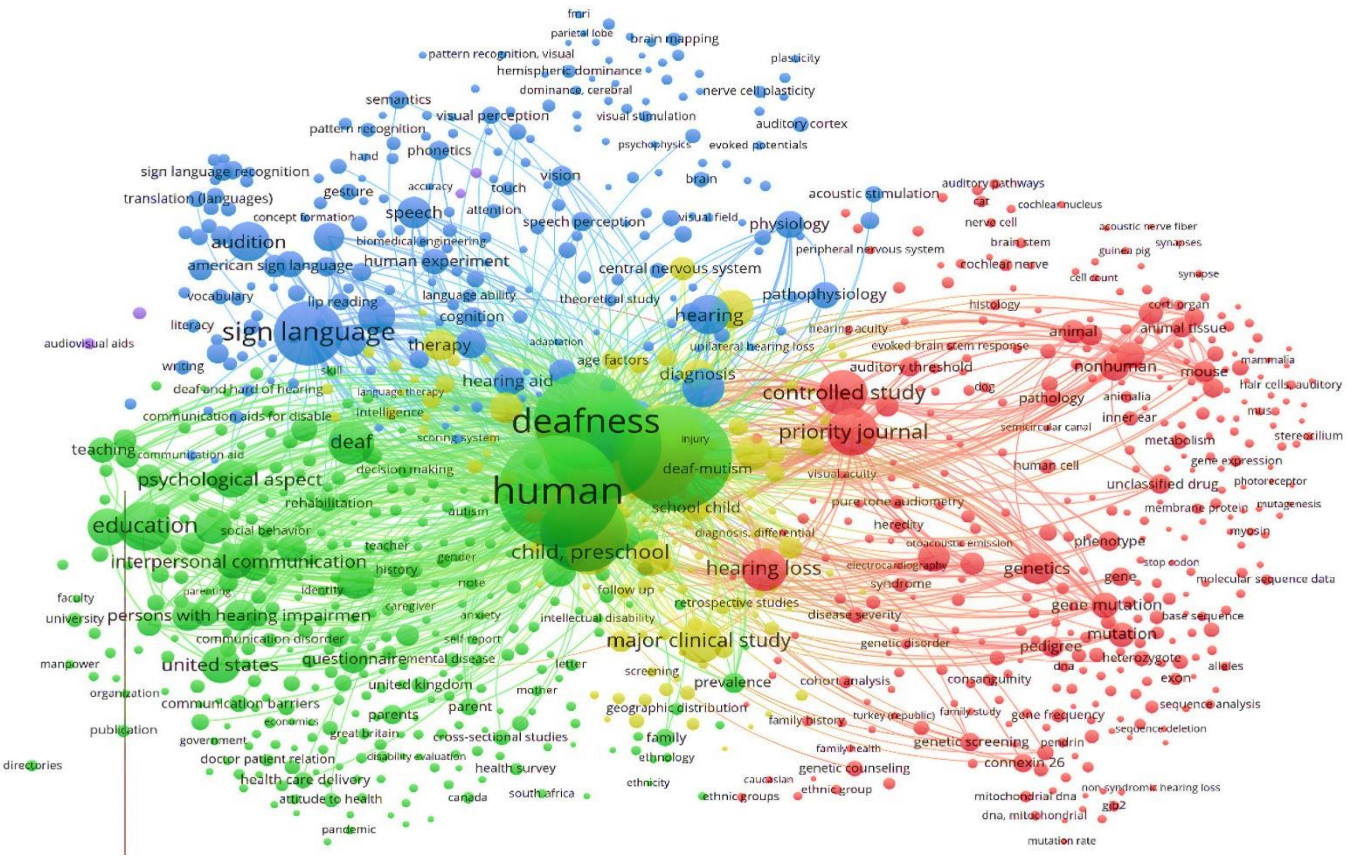

Fig. 9 Cluster with keywords

Figure 9 shows the clustering of nodes by colors. In VOSviewer, there is a configuration to customize the clustering based on the amount of data obtained in the CSV file. In this case, in Figure 9, nodes are shown in green, blue, red, and yellow. Each colored node represents a keyword. It is worth noting that the larger or more intense nodes are those mentioned more frequently in the abstracts of scientific documents.

For the green color, we have keywords like "deafness," "human," "child, preschool," "deaf-mutism," "deaf," "psychological aspect," and "education." In blue, keywords include "sign language," "audition," "speech," "human experiment," "physiology," and "hearing." The red color highlights keywords like "controlled study," "priority journal," "hearing loss," "genetics," "gene mutation," and "mouse." Lastly, the yellow color includes keywords like "major clinical study" and "therapy."

4. Discussion

The interface by tools provided by Scopus, 8,827 scientific documents were analyzed, including articles and conference papers. This contributed significantly to a large amount of data to process, yielding excellent results in achieving the objective of understanding the current state of devices for children with hearing disabilities. The information obtained was processed using Visual Basic Applications and Vosviewer.

Information was analyzed from the years 2002 to 2023, as from this year, scientific production experienced exponential growth in the subsequent years. Twenty years of exploration and discovery have been considered in response to an unmet need dedicated to children and families with this disability. While 20 years of research are not fully represented by over 8,227 papers, this manuscript aims to quantify and discover the most novel technologies related to hearing disabilities.

A search algorithm was devised with its primary focus on devices and hearing impairment. Additionally, keywords related to embedded systems and trends in machine learning or artificial intelligence were added to the algorithm. This led to a reduction from 10,000 documents to the quantity presented in the results. It is worth noting that access to these documents was limited due to access restrictions and the type of documents indexed in Scopus.

Upon examining scientific production, it was observed that the most researched countries are in the United States, with a significant portion of these documents falling into the categories of medicine and social sciences. Furthermore, the weighted average quantity of documents published annually with respect to our algorithms is around 400 documents. Author Emmorey, K. stands out as having the highest number of publications during these years, focusing on hearing disabilities regarding inclusion and social responsibility. Additionally, there are 15 documents emphasizing the search for technological solutions within their primary research line. Lastly, it is important to highlight that 64.1% of the documents fall under the category of articles, while the remaining percentage is lower. However, it is crucial for this research to analyze these documents for a broader sample. Nonetheless, it should be mentioned that a more exhaustive review is needed to avoid bias when processing the information.

Based on [17-18], progress has been made in developing a device for deaf children without resorting to invasive surgery. Thanks to these investigations, there was a bias in searching and including keywords such as GPS, Wifi, Bluetooth, and various keywords related to sensors and technological innovation. However, our research focuses on discovering the current state and reality of technological advancements related to the objective. On the other hand, in [19], the proposed approach addresses the aspects sought in the results of this research. Still, a significant portion of our information is centered on searching for documents and contributions from the scientific community to society.

Finally, this research requires special filtering with experts and expanding the database using the Web of Science platform. While Scopus provides vast information, supporting a platform with unique journals dedicated to medical technology development will enrich the information search, aligning with our methodology's goals.

5. Conclusion

This research successfully achieved its objective of conducting a systematic review to determine the current state of technological support devices for the community of children with hearing disabilities, intending to improve communication for these children and their surroundings.

A total of 8,827 scientific documents from Scopus were processed. The data obtained from Scopus in BibTeX format, processed using VOSviewer and Visual Basic Applications, provided a historical perspective that narrowed down the research timeframe to over 20 years, starting in 2002 and ending on September 5, 2023. It was also discovered that 2022 had the highest number of scientific documents. Furthermore, the United States was found to be the country with the highest research output on hearing disabilities.

In conclusion, it is worth noting that out of the 64.1% of reviewed articles, only 3% were focused on developing or validating a device capable of assisting individuals with hearing disabilities, with only 1.3% emphasizing devices for children. Therefore, it is recommended that future research efforts concentrate on developing cost-effective devices that encompass important associated factors, such as facilitating communication with close relatives or guardians, incorporating a geolocation system, and establishing an emergency communication protocol. As a future prospect, improving the review process by cross-referencing information with Cite Score and other indexed databases is suggested. Additionally, this research proposal aims to initiate a sequence of developments based on the current state of devices and advancements for individuals with hearing disabilities.

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