Deep learning for the identification of autism traits in children through facial expressions: a systematic review

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ABSTRACT

This study employs a bibliometric analysis to examine research on the application of artificial intelligence, specifically deep learning, in the detection of autism traits through facial expressions. Using quantitative methodologies. The analysis revealed a notable growth in scientific output from 2019, with an emphasis on techniques such as convolutional neural networks and systems based on the facial action coding system (FACS-CNN). The results highlight improvements in diagnostic accuracy thanks to the use of deep learning, although challenges related to data quality and availability remain. This study underscores the importance of international collaboration and technological innovation to advance the diagnosis and treatment of autism, offering a comprehensive perspective on current and future trends in this interdisciplinary field.

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1. INTRODUCTION

Autism spectrum disorder (ASD) is a neurological condition that affects a person's ability to communicate, interact, and behave [1]. It is a neurodevelopmental condition that affects a significant part of the child population, exceeding 1%. It is characterized by difficulties in social interaction, communication, and repetitive and restricted behaviors [2]–[4]. ASD symptoms last a person's entire life and affect personal, family, educational, and professional experiences [5]. People with ASD can communicate, interact, behave, and learn differently than most people [6]. ASD usually manifests itself from childhood, although its diagnosis requires specialized skills. Recent research suggests that difficulties in synchronization and motor integration could be fundamental in this disorder, offering a possible way to identify it early [7]. Artificial intelligence is highly effective in the early detection of autism, allowing alarming signs to be identified in preverbal interactions using tools accessible to non-expert observers [8]. Extensive research has been conducted to develop machine learning models, such as an automated model based on infant behavior, to identify ASD in high-risk infants [9]. This model analyzed visual and vocal features derived from the social stress response during mother-infant interaction, indicating the use of machine learning techniques for the processing and analyzing of this data [10]–[13]. Likewise, deep learning, a branch of artificial intelligence inspired by the functioning of the human brain, has revolutionized numerous fields, including health and neuroscience research. Their ability to learn complex representations of data, especially images and signals, has generated significant interest in their application to address challenges in diagnosing and treating neuropsychiatric disorders [14]–[18]. One of the outstanding uses was deep neural networks, which were evaluated to detect ASD from textual statements, specifically from narratives produced by individuals with ASD [19]. Based on statistical algorithms, these learning models are particularly suitable for tackling complex problems involving many options or non-linear processes, overcoming the limitations of conventional computer models in terms of quality and scalability [20]. The lack of accuracy and efficiency in traditional methods of early detection of autism in children poses a significant challenge in the field of research. Face image detection, in particular, is challenging due to the inconsistency in the number and quality of images used for model training, which significantly impacts its performance. This approach offers a valuable tool for early intervention and harm prevention in autistic children during crisis episodes [21].

The model must be able to distinguish between different emotions, which is complicated due to various reasons, such as the different features present in the facial images and the possibility of facial expressions indicating emotions other than the real ones. For example, sad emotions can be confused with emotions of anger, and the same is valid for joy and surprise [19]. Faced with this problem, a more precise and efficient approach is required that allows an early and reliable detection of autism in children. How does the application of deep learning allow the detection of children with autism quickly and effectively using facial features, compared to traditional methods?

The manual diagnosis process for any neurodevelopmental condition is time-consuming and requires extensive behavioral evaluations and analyses [22]. Traditional methods, such as the autism diagnostic observation schedule (ADOS) and childhood autism rating scale, second edition (CARS-2), rely on manual observation of the child's behavior by a doctor. These methods can be subjective, and their reliance on human judgment can lead to errors, potentially delaying the necessary treatment [23]. This highlights the need for more precise and efficient approaches that allow for the early and reliable detection of autism in children.

This study will demonstrate how deep learning's ability to analyze complex data patterns holds promise for automating the diagnostic process [24], [25]. For instance, by applying deep learning algorithms to neuroimaging data, it has become possible to identify neurological variations associated with autism. While this approach allows for accurate predictions of ASD, its implementation can be costly and requires the expertise of specialized medical professionals. In contrast, the use of facial imaging for ASD diagnosis offers a simple and user-friendly approach, eliminating the need for expert intervention or expensive testing [26]. Facial image datasets are valuable in various applications, especially in the field of deep learning, as they offer compelling advantages and are readily available for deep learning algorithms [27]. Moreover, facial imaging is efficient for training ASD diagnostic models due to its inherent features, such as facial recognition and emotion analysis [28], [29].

2. METHOD

Applying deep learning to analyze facial expressions is becoming an innovative and promising tool for the early identification of autism traits in children. Since the manifestations of autism can be subtle and varied, advanced deep-learning algorithms market patterns and characteristics that might go unnoticed by traditional methods. This systematic review addresses the efficacy of these models in accurately identifying autism traits by analyzing large facial datasets. Combining facial recognition techniques with deep neural networks improves diagnostic accuracy and offers a new perspective on early intervention and child development monitoring.

2.1. Research question

In this systematic review, we investigate how the application of deep learning allows the rapid and effective detection of children with autism from facial features, compared to traditional detection methods. The population, intervention, comparison, outcome (PICO) methodology provided a logical structure to divide the research question. In the context of this research, the population of interest (P) is considered to be children who are at potential risk for autism or those who have already been diagnosed with this developmental disorder. The intervention (I) that is examined involves applying advanced deep learning techniques specifically designed to analyze and recognize complex patterns present in the facial expressions of these children. As a point of comparison (C), traditional methods of autism screening are studied, including, but not limited to, clinical observations by health professionals and conventional psychological assessments. These methods have historically been used as fundamental tools in the autism diagnosis process. The expected result (O) of this research is to determine the relative efficacy of deep learning compared to traditional methods of autism detection. A table has been developed to provide a summary and accessible view of the essential components of the research. As shown in Table 1, it represents a visual resource intended to provide a quick and clear understanding of the fundamental aspects of the study. It includes critical elements such as the research question, the division of PICO, and the primary or essential sources used in the review. On the other hand, Table 2 presents the component questions of PICO for a better understanding and application of the PICO model in the research.

Table 1. Search synthesis

Research question	How does the application of deep learning allow the detection of children with autism quickly and effectively from facial features, compared to traditional methods?
Pico division	Q: This review focuses on children with autism. I: The development of a system based on deep learning that enables the detection of children with autism is examined. The C: Compared to the combination of clinical observations and developmental assessments currently used. La O: The goal is to achieve an effective and rapid diagnosis of the autism spectrum through the use of the system based on deep learning.
Key sources	- Raya *et al.* [4]: ASD affects approximately 1 in 160 children and can be detected from six months, being most common between two and four years of age. Although ASD studies focus on deficits in social skills, the significant impact of repetitive motor behaviors on every day and social life is often overlooked. - Hassouneh *et al.* [27]: deep learning has great potential to revolutionize the field of ASD diagnosis. Its ability to analyze complex patterns and data representations offers great promise for automating the diagnostic process. - Liberati [29]: Traditional facial expression analysis relies on manual rules and features, which can limit the capture of facial complexity and reduce accuracy due to subjectivity in defining these rules. On the other hand, the use of deep learning, such as convolutional neural networks (CNNs), enables machine learning of relevant features of facial expressions, achieving greater accuracy, generalizability, and scalability by detecting complex patterns more effectively. - Wan *et al.* [17]: Diagnosing ASD using facial imaging provides a quick and accessible way to perform an initial assessment, avoiding the need for expert intervention or expensive tests. In addition, facial imaging datasets show great potential as a valuable resource for the development of accurate deep learning models in ASD diagnosis.

Table 2. PICO component questions

COMPONENTS
RQ1: What are the most common clinical features observed in children with autism?
RQ2: What are the most effective and accurate deep learning approaches and techniques for the early detection of autism in children?
RQ3: What is the effectiveness of traditional methods that combine clinical observations and developmental assessments in the early detection of autism in children?
RQ4: How can emerging technologies, such as deep learning and artificial intelligence, support or improve the autism diagnosis process?

2.2. Search strategy

The primary focus of the search strategy for this systematic review is to comprehensively collect evidence and information from three critical databases: Scopus, PubMed, and EBSCO. The PICO approach will be used to structure the search effectively and answer the research question. Table 3 details the PICO elements and their associated key terms, facilitating the identification of essential concepts defining the search in the selected databases. Regarding the population, it focuses on children diagnosed with ASD at an early age and in school, and the intervention focuses on the implementation of deep learning algorithms for the early detection of autism concerning facial expressions. In terms of comparison, traditional methods, such as clinical observation and developmental assessments, were considered, while the result is directed toward the accurate and timely diagnosis of ASD.

Table 3. PICO components and keywords

Component	Keywords
P	Children, autism, schoolchildren, preschoolers, minors, childhood autism, early diagnosis of autism
I	Deep learning, artificial intelligence, autism detection, machine learning, facial expression analysis, autism assessment using facial expressions, autism trait identification
C	Autism diagnosis by voice, body movement analysis, psychological evaluations, autism clinical observation
O	Facial expressions diagnosis, gestures, effectiveness, fast detection, deep learning algorithms, image processing

Table 4 provides the search equations for each PICO component in the PubMed, Scopus, and EBSCO databases. These equations were meticulously designed, employing logical operators and related terms to ensure a thorough search for information across all platforms. By incorporating a variety of synonyms and related keywords, the search equations aim to capture a comprehensive range of relevant studies and articles. This approach helps to minimize the risk of missing critical literature and ensures that the search results are as inclusive and accurate as possible.

This strategy was designed to comprehensively address the research question of applying deep learning to identify autism traits in children through facial expressions through a systematic review. Inspired by the PICO methodology, this study sought to guarantee a comprehensive and specific search. Three critical health and science databases were used to include relevant and up-to-date studies: Scopus, PubMed, and EBSCO. The structure and methodological approach of the search technique was based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, which allowed for an organized and transparent process. The inclusion and exclusion criteria were established to select high-quality, relevant studies. Incorporating these tools and methodological strategies sought to provide a complete and rigorous analysis of the application of deep learning in detecting autism traits by studying facial expressions in children. In Tables 5 and 6, this can be observed more dynamically.

Table 4. Search equations by PICO component in Scopus, PubMed, and EBSCO

Database	Search equation by component	Number of results
Scopus	(TITLE-ABS-KEY (autism) OR TITLE-ABS-KEY (autism AND spectrum AND disorder) OR TITLE-ABS-KEY (asd) AND TITLE-ABS-KEY (facial AND expressions) OR TITLE-ABS-KEY (emotional AND expressions) AND TITLE-ABS-KEY (identification) OR TITLE-ABS-KEY (detection) OR TITLE-ABS-KEY (diagnosis) AND TITLE-ABS-KEY (deep AND learning) OR TITLE-ABS-KEY (deep AND neural AND networks) OR TITLE-ABS-KEY (neural AND networks) AND TITLE-ABS-KEY (children) OR TITLE-ABS-KEY (infants) OR TITLE-ABS-KEY (minors))	60
EBSCO	("autism spectrum disorder" OR ASD) AND ("deep learning" OR "machine learning") AND "detection"	49
PubMed	(("children" OR "autism" OR "school-aged" OR "preschoolers" OR "minors") AND ("deep learning" OR "artificial intelligence" OR "autism detection" OR "machine learning") AND ("voice diagnosis" OR "body movement diagnosis" OR "traditional diagnostics") AND ("facial expression diagnosis" OR "gestures" OR "effectiveness" OR "accuracy" OR "rapid detection"))	103

Table 5. Inclusion criteria

Inclusion criteria	Justification
Scientific articles	Scientific articles published in academic journals guarantee the reliability and methodological rigor of the research, which contributes to the credibility of the results obtained.
Relevance in artificial intelligence and derivatives	Studies must address topics related to artificial intelligence and its ramifications, such as machine learning, deep learning, among others.
Studies with a specific focus on the detection of neurodevelopmental problems	It ensures that the review focuses on the problem of interest.

Table 6. Exclusion criteria

Exclusion criteria	Justification
Conference paper	Need to maintain a standard of quality and rigor in systematic review.
Studies unrelated to the detection of neurodevelopmental problems	Those studies that are not directly related to the topic of interest, such as those that address completely different topics.

The methodological robustness of the systematic review was strengthened by this approach, which ensured coherence and breadth in selecting relevant articles to be used in the review. Figure 1 illustrates the implementation of the PRISMA methodology and the careful attention to the established inclusion and exclusion criteria, which facilitated the identification of relevant sources that would support the objectives of this systematic review. Furthermore, the systematic approach helped minimize bias and ensure the replicability of the selection process. Consequently, the results provide a comprehensive and well-founded perspective on the topic of study, significantly contributing to the existing body of knowledge.

As illustrated in the figure, the PRISMA methodology is clearly demonstrated for its capacity to standardize data presentation, enhance the reproducibility of studies, and enable readers to critically assess the strength and dependability of the results in systematic reviews and meta-analyses [30]. The initial phase of the process, the central databases such as Scopus, PubMed, and EBSCO were selected, which offered a wide variety of information on artificial intelligence and its applications. Duplicate records were also eliminated to prevent the entry of redundant information. In the second phase of the process, studies were selected by applying predefined inclusion and exclusion criteria. An initial evaluation was carried out based on titles and abstracts, discarding those studies that did not meet the established criteria. In addition, additional verification of reports that could not be obtained initially was carried out to ensure that all appropriate sources were considered. In this final stage, it was possible to identify and choose the relevant documents or studies that met the criteria established previously.

The PRISMA methodology, as shown in the figure, significantly enhances the clarity and transparency of research. It provides a structured framework that facilitates the clear and complete presentation of each phase of the review process, from the identification of relevant studies to the synthesis of results [31]. This methodological approach not only promotes clarity in research but also enhances the reproducibility and reliability of the findings by meticulously documenting each step of the review process. In the context of detecting autism in children, PRISMA plays a vital role in the systematic evaluation of the effectiveness and applicability of artificial intelligence technologies. This includes specific areas such as machine learning and deep learning, which are increasingly being used to enhance diagnostic accuracy and personalized interventions.

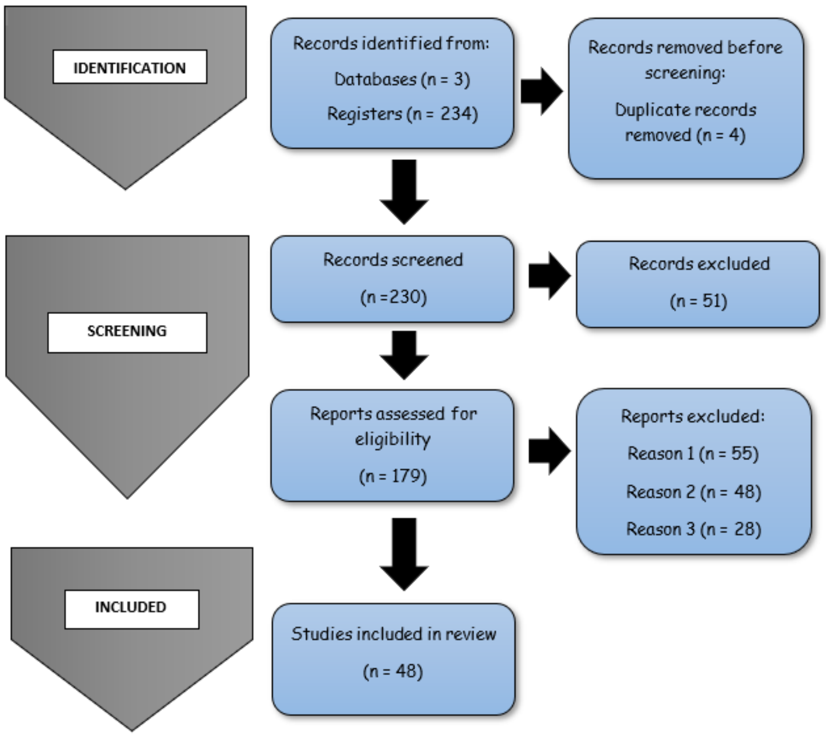

Figure 1. Identification of research through the use of the PRISMA database and bibliographic records

3. RESULTS AND DISCUSSION

This study provides a detailed literature review and comprehensive research analysis. The first section highlights the interrelationships between the use of deep learning and the detection of autistic traits in children through their facial expressions, accompanied by a visualization of the density of these studies. The second section examines the scientific gaps identified in the reviewed articles, proposing the creation of a technological model for implementing deep learning algorithms that optimize and improve the effectiveness of detecting autism traits.

3.1. Bibliometric analysis

Bibliometric analysis, a research technique that employs quantitative and statistical methods, plays a crucial role in academic research. It helps to identify trends and patterns in the publication of articles, such as changes in research focus over time. This technique also analyzes collaborative networks between authors and institutions, revealing connections and partnerships that drive research. Additionally, bibliometric analysis maps the intellectual and thematic structure of a field, showing how different areas of study are related. Furthermore, it evaluates the impact and influence of publications, authors, and institutions by examining citation metrics and publication reach, thus highlighting key contributors and significant works in the field [32].

Figure 2 shows the network map provided, which shows four thematic groups that summarize significant relationships between the key terms. In the first group, focused on autism, connections between “autism,” “CNN,” “emotional recognition,” and “facial expression” stand out. This suggests a profound interrelationship between autism, emotional recognition, and facial expressions through using CNN. The second group, focused on deep learning, reveals connections between “machine learning,” “emotional recognition,” and “facial expressions,” indicating a focus on the application of deep learning techniques for the recognition of emotions and facial expressions. The third group, related to ASD, is connected to “convolutional neural networks,” underscoring CNN's application specifically in the context of ASD. Finally, the fourth group focuses on “artificial intelligence,” showing connections with “machine learning and deep learning,” highlighting the application of artificial intelligence in detecting autism traits. Each group demonstrates meaningful connections that illustrate how these concepts are interrelated in their respective fields of study.

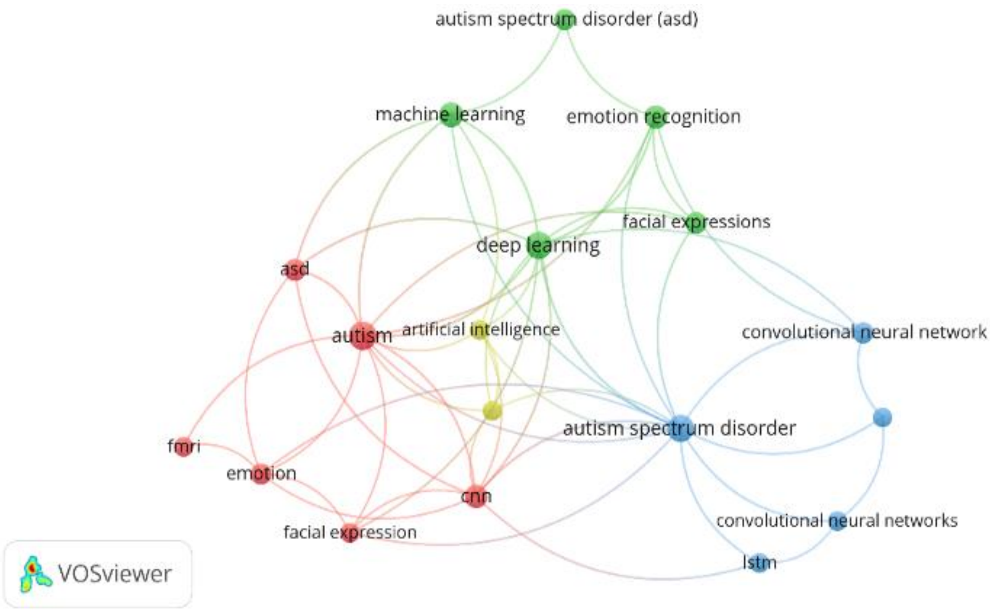

Figure 2. Connections between key terms through bibliometric mapping

3.2. Manuscript analysis

In the initial stage of the search, three (3) databases containing research results were used, which led to the identification of two hundred and twelve (212) documents. Subsequently, a selection process was carried out using the PRISMA methodology. This process included eliminating duplicate documents and excluding documents that were not relevant to the study's topic. Because of this meticulous procedure, forty-eight (48) articles were finally selected, as presented in Table 7.

Phase 1 was dedicated to the systematic search and collection of documents relevant to the research topic. This phase involved methodically querying databases and gathering a broad range of articles and studies. In phase 2, the process will involve removing duplicates and excluding articles that do not pertain to the specific topic of interest. This step ensures that the dataset is refined and relevant to the research objectives. Finally, in phase 3, the review will culminate in the identification of 48 articles that are considered relevant to the research. These articles will be selected based on their relevance and contribution to the research questions, providing a focused foundation for further analysis.

The table summarizes the search for and selection of research articles from various databases. Initially, three databases were used: Scopus, EBSCO, and PubMed, identifying 212 articles. Specifically, 60, 49, and 103 articles were found in Scopus, EBSCO, and 103 in PubMed. After applying a rigorous filtering process, which included eliminating duplicates and excluding irrelevant articles, 48 articles considered relevant to the research were finally selected. Of the articles initially identified, 17 were selected from Scopus, 13 from EBSCO, and 18 from PubMed. In addition, Figure 3 shows which country has produced the most articles, identifying coincidences with the keywords in this review. These studies focused on autism research and the application of deep learning to facial feature detection. India led the way with 12 significant studies in this field, followed by China with 10 and the United States with 6. Italy stood out with 4 relevant contributions, while Spain, Egypt, and France contributed 2 studies each. Countries such as Tunisia, Malaysia, Korea, Australia, Oman, Pakistan, Saudi Arabia, Germany, and Brazil also contributed 1 article respectively, reflecting geographical diversity in the research reviewed.

Between 1979 and 2024, the evolution in the publication of scientific articles related to applying deep learning to identify autism traits in children through facial expressions showed a notable increase in interest and research in this field. In 1979 and 2009, only one paper was published per year, and from 2014 to 2016, the trend continued with one annual publication. 2018 featured only one article. However, as of 2019, with 5 articles, a significant increase was observed, reaching a peak in 2021 with 14 articles. This sustained growth includes 8 items in 2020, 4 in 2022, 7 in 2023 and 4 in 2024. This trend reflects a growing interest in and advances in research related to the use of advanced technologies and autism diagnosis, highlighting the relevance of the topic in the scientific community and critical periods of increased scientific production, which are essential for the development of future research and systematic studies, for more details, as shown in Figure 4.

Table 7. Search results

Database type	Name	Initial search	Final selection
Main	Scopus	60	17
Secondary	EBSCO	49	13
	PubMed	103	18
	Total	212	48

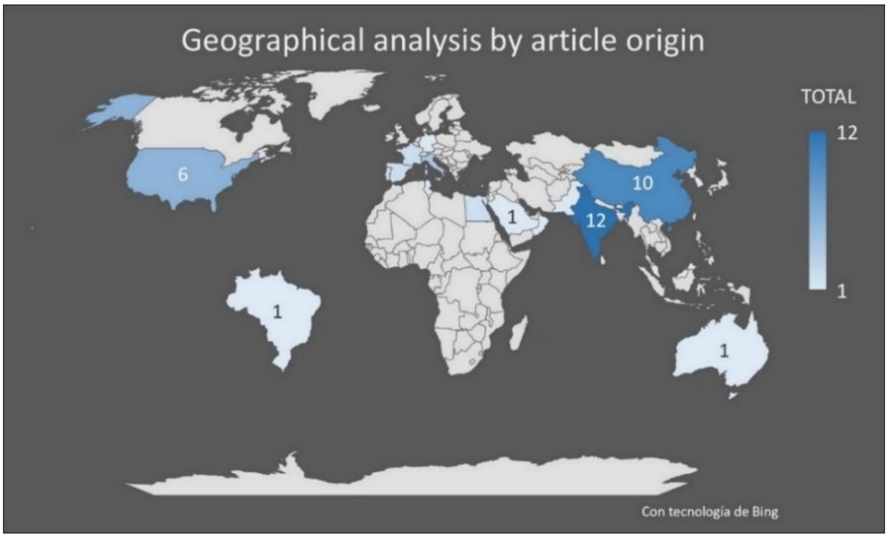

Figure 3. Geographic analysis by article origin

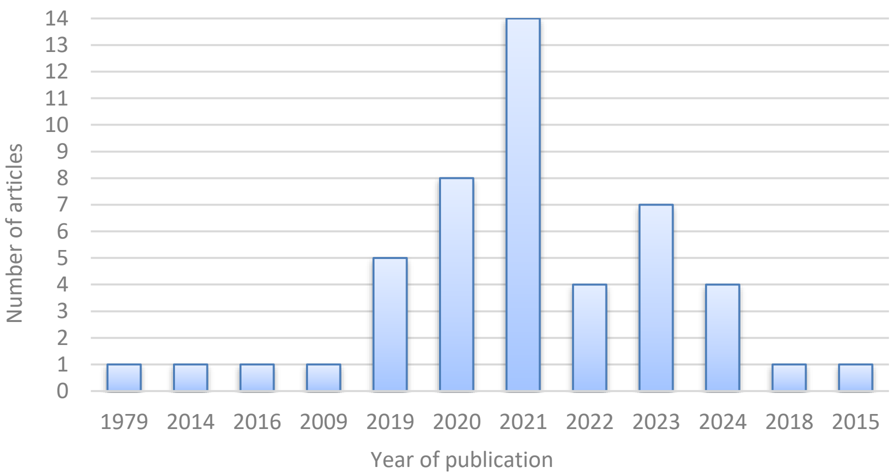

Figure 4. Analysis of articles according to the year of publication

3.3. Deep learning in the detection of autism

Autism or autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by difficulties in communication and social interaction, as well as repetitive and restricted behaviors [33]. Children with autism often exhibit symptoms from an early age, around the age of 2-3, and show an indifference to their surroundings [34]. Although there is no cure for autism, a variety of behavioral therapy and rehabilitation approaches have been developed to improve the social functioning and quality of life of those affected. Traditional methods for diagnosing ASD primarily rely on experts' observation and clinical evaluation without incorporating advanced technological tools. These methods include assessment based on the diagnostic and statistical manual of mental disorders, fourth edition, text revision (DSM-IV-TR) and international classification of diseases, 10^{th} revision (ICD-10) criteria, various autism assessment scales, such as the childhood autism rating scale (CARS) and the child with autism behavior scale, as well as interviews and questionnaires aimed at parents or caregivers [35].

However, these approaches have significant limitations, such as the influence of subjectivity and biases of professionals, which can result in diagnostic errors and omissions. Furthermore, the traditional diagnostic process generally requires several hours per patient, which represents a considerable burden for professionals. Studies have found that deep learning techniques offer significant improvements in accuracy for detecting and diagnosing autism spectrum disorder compared to traditional methods that rely on clinical observation of behaviors. These techniques enable process automation, thereby reducing user burden and associated costs. In addition, they can integrate data from various modalities to further improve diagnostic accuracy [35]–[38]. Table 8 outlines the foundational bases of the studies conducted, categorizing them into three main areas. The first category focuses on recognizing facial expressions and emotions; the second category examines the use of deep learning techniques, and the final category assesses the efficiency of deep learning in early detection. These sources underscore the importance of deep learning in the early identification of emotions and conditions, highlighting its transformative potential in this field.

Table 8. Basis of the studies carried out

STUDY	REFERENCE
Recognition of facial expressions and emotions	[30], [39]–[47] [48]–[52]
Deep learning use	[50], [53]–[60] [61]–[70]
Deep learning efficiency and early detection	[42], [48], [71], [72]

3.4. Deep learning models

Studies have found that facial expressions can provide emotional information, but limitations exist. For one, universal facial expressions can distinguish between positive and negative emotions. However, they do not always provide precision about specific emotions. Also, some people may hide their expressions. Therefore, detailed measurement of facial activity may be necessary to reveal reliable clues [53]. According to the research reviewed, researchers continue encountering significant challenges distinguishing between normal and autistic faces. However, machine learning and deep learning techniques have made it possible to advance in the early detection of ASD through the analysis of facial expressions [35]. One of the outstanding proposals is the development of hybrid neural networks that combine convolution architectures (CNNs). This makes it possible to leverage the capabilities of both approaches for more accurate and complex autism detection [35], [36]. In addition, systems based on the facial action coding system (FACS-CNN) to extract distinctive facial features between children with and without ASD have been explored [37]. These models have achieved detection rates of around 90% in reference datasets [38]. Other studies have compared deep learning architectures, such as VGG16, ResNet101, and MobileNet, for facial feature analysis, gaze tracking, and feature map extraction [5]. These approaches are practical for classifying images of people with autism. However, the authors note that challenges are still related to the availability and quality of facial image datasets of autistic children [35].

Table 9 provides a compilation of deep-learning models used for the detection of facial traits associated with autism. Among these, ResNet has been referenced in several studies due to its ability to enhance pattern recognition in images, instilling confidence in its potential. Additionally, the Xception model stands out for its efficient architecture in feature extraction, promising efficient and accurate results. Finally, CNNs have proven to be a powerful tool for facial expression analysis, yielding promising results in the classification of images of individuals with ASD, further reinforcing the potential of these models.

Table 9. Deep learning models

Model	Reference
ResNet	[29], [34], [54]–[56], [68]
Xception	[29], [34], [69], [70]
CNN	[59]–[68] [69], [71], [72]

4. CONCLUSION

The systematic review employed both PICO and PRISMA methodologies to comprehensively investigate the application of deep learning techniques in detecting autism traits through facial expressions. Initially, 212 articles were identified across three significant databases, from which 48 were selected based on rigorous inclusion criteria. This selection process ensured a high standard of relevance and quality in the studies reviewed. A bibliometric analysis of the selected articles highlighted a growing global interest in this research area, with India, China, and the United States emerging as prominent leaders. Deep learning has the potential to significantly enhance diagnostic accuracy by analyzing facial expressions, which in turn could lead to more precise and timely diagnoses. This improvement underscores the need for continued research and development to optimize diagnostic tools and advance early treatment strategies for autism, ultimately contributing to better outcomes for individuals affected by the condition.

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AUTHOR CONTRIBUTIONS STATEMENT

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Heli Cordova-Berona	✓	✓		✓	✓			✓		✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest. They have not received any type of funding from entities that could influence the results or conclusions of this work.

INFORMED CONSENT

As this is a systematic review of previous studies, no human participants were directly involved in this research. Furthermore, all studies included in the review reported obtaining informed consent from participants, as stated in their respective original articles.

ETHICAL APPROVAL

This research is a systematic review of previous studies and did not involve the collection of original data from human or animal participants. It should be noted that all studies included in the review complied with relevant ethical regulations and obtained ethical approval from their respective institutional review boards. Furthermore, the data and results presented in this research are true and have been obtained and analyzed in an objective and transparent manner.

DATA AVAILABILITY

Data availability does not apply to this article, as no original data were created or analyzed in this study, and this research is a systematic review of previously published studies. Furthermore, the data supporting the findings of this review are contained in the included studies, which are publicly available and are appropriately cited in the references of this study. It should be noted that the studies used in this analysis contain all relevant data, including DOI and other links, which readers can consult for more details about the results and methodology used.

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