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Cover Page Footnote

Iam grateful to Dr Hany Ali Elghaish for his valuable contributions and insights throughout the review process.

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Early Autism Detection using Machine Learning Techniques: A Review

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***Abstract*- This article provides a comprehensive literature review on technology-based interventions for Autism Spectrum Disorder (ASD). It emphasizes the challenges in early detection and treatment of ASD, highlighting the spectrum nature of the disorder. The review discusses traditional diagnostic strategies such as behavioural observations, developmental screening and medical testing and goes on to explore advanced machine learning and deep learning models, including SVM, k-nearest neighbours, decision tree and LSTM, for predicting ASD characteristics in toddlers and children. Additionally, recent techniques employing more than ten strategies for ASD detection are summarized and various datasets used in early detection are described. The study underscores the utility of artificial intelligence in early ASD detection and recommends integrating advanced techniques, such as eye tracking, EEG, brain imaging, exome sequencing, urine analysis and behaviour coding, with conventional methods for potentially earlier and more effective solutions.**

***Keywords*- ASD; autism; EEG; MRI; Eye tracking; Genetic testing; Behaviour coding; Urine analysis; Gender; social media.**

I. INTRODUCTION

Autism spectrum disorder (ASD) is a developmental disability that affects the brain. Differences in attitudes, communication and learning are evident. The causes of ASD are not fully understood, but are believed to be a combination of genetic, environmental and biological factors. Symptoms of ASD can vary widely, and diagnosis can be difficult because there is no clinical diagnosis. Treatment aims to reduce symptoms and improve daily functioning and early intervention is essential for optimal outcomes[1].

Behavioural therapy is the only proven treatment for core ASD symptoms, especially if it is started at an early age[2]. Risk factors for ASD include having a sibling with ASD, certain genetic conditions, congenital complications and older parents. ASD occurs in all racial and socioeconomic groups and is more common in children. If parents are concerned about their child's development, they should consult with a health care professional and consider referring them to a specialist for further evaluation. Early intervention can be very helpful for children with ASD[1].

Before 2018, the early detection of autism relied on monitoring signs of autism in children from at least 12 months of age as some cases could be detected by 18 months and signs may be evident even earlier through signs include atypical social and communication behaviour, repetitive movements and intense reactions to sensory stimuli. Some children may show hints of autism in their first months, while in others, behaviours become more obvious later. Special attention was given to the development of children between 18 and 24 months of age, a period during which many (but not all) cases of autism were detectable. However, autism was typically not identified before four years of age, often more than two years after parents first sought medical attention, so it is recommended that all children be screened for autism spectrum disorder at their 18- and 24-month well-child checkups. Initial contacts usually resulted in misplaced reassurance, followed by a series of professional consultations before a definitive diagnosis of autism was made which leads to a long delay that frustrated parents [1]. Therefore, the importance of this study is to distinguish this literary critic and provide a broad cognitive view in this field, using dense and diverse strategies that enhance the early detection of the disease and confirm the correct diagnosis, which increases its strength and ability to provide accuracy and performance about the data used in detection through machine learning through the integration of algorithms and artificial intelligence. This literary critic discusses 14 strategies of dealing with the autism early detection based on different modalities and machine learning techniques that help in early detection, as more than one way can be combined to take advantage of the advantages of each method with the other, for example, the study stated that it is possible to combine magnetic resonance images and images of EEG signals filmed for brain activities and also it is possible to combine images of EEG

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signals filmed for brain activities and tracking the eye movement of the person suspected of injury.

The review will address the gaps and challenges in this area over the past five years by clarifying multiple ways to detect the disease and choosing the appropriate detection method for the person to be examined based on his symptoms. It highlights the need for further research to improve and validate existing methods and develop new methods for the early detection of autism spectrum disorder through the possibility of integrating more than one method together. In addition, it will explain the implications of early detection of enabling timely intervention and the possibility of improving long-term outcomes for individuals with autism spectrum disorder. By comprehensively reviewing and integrating existing literature, this review seeks to provide researchers, clinicians and policymakers with a broader understanding of progress, challenges and future directions in the early diagnosis of ASD, with the primary goal of helping to continue efforts to improve early detection strategies and the timing of interventions for individuals with ASD. This literature review consisted of two main parts, the first part dealt with the early detection of autism through 14 different strategies and the second part dealt with the data used in detection through machine learning. Different methods for autism early detection using Electroencephalogram (EEG) signals, brain imaging by Recombine brain imaging by MRI and Electroencephalogram (EEG) signals, Eye-Tracking, combine Eye-Tracking and Electroencephalogram (EEG) signals, Exome Sequence Testing, Facial Expressions, Behaviour Coding Measures, Blood Biomarker, Urine Analysis, Vision Screening, Nervous Oscillation, Gender Types and Influence of social media. Autism Early Detection research strategies are summarized in Figure 1. The rest of this review is organized as follows: Section 1 presents fourteen strategies for autism early detection. Section 2 presents Comparative Analysis of Machine Learning Techniques for autism early detection. Section 3 presents Real-World Applications of Machine Learning Techniques in Early ASD Detection. Section 4 presents Some of the existing autism datasets and their categorization are summarized in Figure 2. Section 5 presents Data Quality Issues in Autism Early Detection Using Machine Learning.

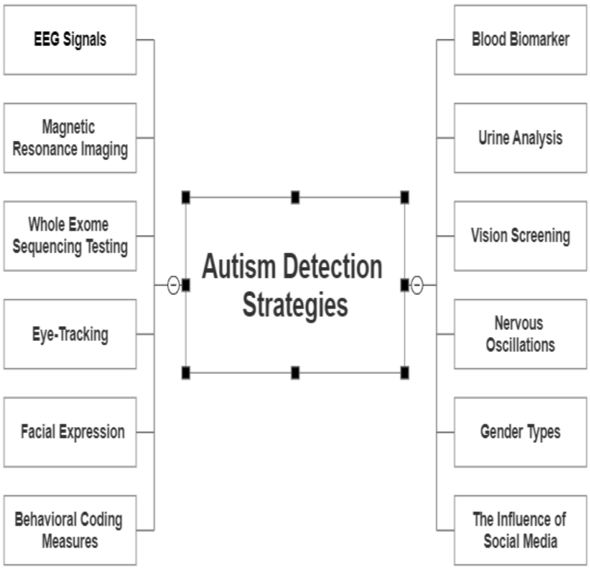

Figure 1. Autism Early Detection research strategies.

1. *Recent Research Methodologies in Early Autism Detection*

This review has two sections. The first section explained methods to detect ASD and the second one has data that can be used in detecting ASD. First section includes 14 strategies depending on Brain Activity, Genetics, Behavior, Gender, biomarkers test and combination between two different strategies. Brain Activity includes EEG (brainwaves) where Electrodes measure electrical activity, looking for patterns in person with ASD ,MRI scans where detailed pictures of the brain help see if there are any structural differences, Nervous Oscillation where show brain wave differences between ASD and typically developing individuals. Genetics includes Whole Exome Sequencing Analyzes a child's genes to identify potential markers for ASD.

Behavior includes Eye Tracking which Tracks eye movements to understand how a child pays attention to social cues ,Facial Expressions that Analyzes facial expressions to see how a child interprets emotions, Behavior Coding that observes and records behaviors to identify patterns and develop interventions and social media and digital apps to identify autism symptoms and overcome diagnosis barriers. Biomarkers test such as Blood Biomarkers and Urine Analysis. combination between two different strategies like combinations with EEG&MRI and EEG& Eye tracking.

The second section explained Datasets used in this research come from studies involving person with and without ASD. This data includes brain scans, genetic information, recordings of behavior, Demographic, and eye movements.

Autism Early Detection research strategies Comparison are declared in Table 1 and the available datasets and the applied approaches on it are referenced in Table 3.

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1.1. Autism Early Detection based on EEG signals

EEG signals are recorded using electrodes placed on the scalp and provide a non-invasive way to study the brain's electrical activity. Recent studies have shown that EEG signals can be used as digital biomarkers for early detection of autism spectrum disorder (ASD)[3]. Additionally, EEG signals have been used to monitor the effectiveness of ASD treatments. EEG-based biofeedback and neurofeedback techniques have been used to improve cognitive and social functioning in patients with autism spectrum disorder[4]. By recording and analyzing EEG signals, researchers and clinicians can gain insights into the underlying neural mechanisms that contribute to autism spectrum disorders and develop more effective treatments to improve outcomes for individuals with the disorder.

The article[3] in uses EEG measures as clinically meaningful indicators of atypical brain development in infants born mothers that have a previous child diagnosed with ASD. The study recruited 99 high-risk children who were 3 months old at the time of recruitment to 36 months of age. Statistical learning approaches applied non-linear features extracted from the EEG signals. Prediction is that EEG measurements conducted at the age of three months of development have high sensitivity, specificity and positive predictive value more significant than 95% at some ages. Moreover, there was a significant relationship between EEG assessed at three months and Autism Diagnostic Observation Schedule (ADOS) calibrated severity score which is a standardized measure commonly used in autism diagnosis. This implies that EEG measures may serve as relevant digital biomarkers for early diagnosis of ASD. This paper [5] shows how EEG could be used to cheaply, noninvasively monitor atypical brain development in ASD affected infants, which can be improved through early interventions.

The paper in presents a use of EEG based biomarkers for ASD and provides essential guidelines for pre-processing and feature analysis. Some of these methods include ICA and wavelet-based analysis used to remove noise and extract features. accuracy: 93% with Random Forest and Correlation-based Feature Selection. Although the paper is cheap and precise, it has a small number of participants and should undergo an additional testing in the future. It contributes to a reliable and affordable assessment method for diagnosing ASD enabling, therefore, early detection. The study is based on an 89-participants control group for autism (low risk) and 99-participants high risk group for autism. One of the research possibilities could be looking for new autism biomarker for exact early diagnostics.

The paper [6] proposes an automated ASD prediction method using EEG signals converted to images and analyzed through advanced statistical techniques. This approach aims to enhance ASD detection speed and accuracy, potentially improving service quality for individuals with ASD. Despite limitations such as small sample size, the study offers a novel, efficient method for ASD diagnosis, showcasing the potential of EEG signals in understanding and predicting autism spectrum disorders.

The research in [7] proposes an automated ASD diagnosis method using unprocessed EEG data and machine learning techniques, achieving high classification accuracy with SVM outperforming KNN. Despite limitations like small sample size, the study offers an objective, quantitative criterion for ASD diagnostics, potentially applicable to other neurological conditions. The paper explores various EEG analysis approaches, including spectral analysis and brain network topology, contributing to the field of ASD diagnosis.

The authors in [8] investigate deep learning algorithms to distinguish EEG signals of autistic and non-autistic children, using a multilayer perceptron network for classification. This research offers a novel neurophysiological diagnosis method for ASD based on EEG and deep learning, potentially enhancing detection, early intervention, and treatment outcomes. While the study has limitations, such as a need for more detailed dataset information, it suggests promising directions for future work, including larger sample sizes and real-world clinical validation. The study in [9] proposes an ASD detection method using EEG data, involving signal preprocessing, time-frequency spectrogram transformation, and SVM classification, achieving 95.25% accuracy in cross-validation. This approach shows promise as a decision support tool for autism diagnosis and potentially other neurological disorders. The paper also acknowledges alternative EEG-based ASD diagnostic methods, including functional connectivity measures, spectral power analysis, and speech-related EEG measurements.

The authors in [10] propose an ASD diagnosis method using EEG data, employing signal pre-processing, spectrogram images, and both machine learning and deep learning models. The deep learning-based model achieved a higher accuracy rate of 99.15%, suggesting potential for device-assisted clinical trial protocols for ASD. In [11], a deep-package architecture for ASD detection is proposed, with ResNet50 showing remarkable efficiency, offering a comprehensive analysis of modern deep architectures for ASD diagnosis using EEG signals. Both studies contribute to advancing automated ASD diagnosis methods, with potential for future research exploring other data types and addressing clinical implementation challenges.

The paper [12] proposes an efficient method for diagnosing autism spectrum disorder (ASD) using EEG signals, addressing limitations of previous methods like costly MRI scans.

The approach involves preprocessing EEG signals, extracting features using discrete wavelet transform, and applying various classifiers including neural networks, SVM, KNN, and LDA. While the method offers a non-invasive and cost-effective diagnosis solution, its limitations include a small

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dataset and limited population representation, suggesting future research directions to improve generalizability and explore additional cost-effective diagnostic methods for ASD.

The article [13] proposes an automated approach for diagnosing Autism Spectrum Disorder (ASD) using EEG signals, combining flexible analytic wavelet transform and multiscale permutation entropy features. The method employs both traditional machine learning algorithms and a convolutional neural network (CNN), with the CNN achieving high accuracy in identifying ASD patients. While the study demonstrates promising results for early ASD detection and potential improvement of diagnostic processes, it is limited by a small sample size and lacks comparison with other methods, suggesting future research directions including larger datasets and exploration of alternative non-invasive, cost-effective ASD detection techniques.

The study [14] presents a new framework for ASD detection using wearable EEG sensors, incorporating on-node feature extraction and machine learning algorithms to improve accuracy and reduce power consumption. This approach aims to provide an objective and efficient method for ASD diagnosis, potentially enabling early prediction and intervention to improve outcomes for individuals with ASD. While promising, the study acknowledges the need for addressing real-world implementation challenges, using larger datasets, and optimizing classification models to enhance scalability and accuracy. The research highlights the potential of EEG-based methods in ASD diagnosis but emphasizes the necessity for larger, more diverse studies and comparison with established diagnostic criteria to validate these methods for clinical adoption.

1.2. *Autism Early Detection based on brain imaging by MRI*

MRI (Magnetic Resonance Imaging) is a medical imaging technique that uses strong magnetic fields and radio waves to create detailed images of the body, including brain structural MRI (sMRI) and functional MRI (fMRI). Structural MRI (sMRI) is widely used to investigate brain morphology due to high contrast and spatial resolution. Studies have used various MRI techniques such as sMRI, fMRI and diffusion tensor imaging (DTI) to capture the effects of ASD on brain structure and function[15].

The study in [16] presents a novel approach for analyzing fMRI data to detect autism spectrum disorder (ASD) using a combination of sliding window techniques and 3D convolutional neural networks.

The method, which leverages both spatial and temporal information, demonstrates improved classification accuracy for ASD compared to traditional machine learning models. While promising, the study has limitations including a lack of comparison to other deep learning methods and the need for validation on larger datasets. Despite these constraints, the research shows potential for advancing our understanding of ASD's neural signatures and could contribute to improved screening and treatment methods in the future.

In[17], the study presents a novel approach for analyzing fMRI data to detect autism spectrum disorder (ASD) using a combination of sliding window techniques and 3D convolutional neural networks, leveraging both spatial and temporal information. The method demonstrates improved classification accuracy for ASD compared to traditional machine learning models and provides visualization of spatial features, offering insight into ASD's neural signatures. While promising, the study has limitations including a lack of comparison to other deep learning methods and the need for validation on larger datasets. Despite these constraints, the research shows potential for advancing ASD understanding and could contribute to improved screening and personalized treatment strategies, pending further testing and validation.

This study demonstrates the potential of using machine learning and fMRI data to objectively grade autism spectrum disorder severity, achieving 78% accuracy in classifying individuals into mild, moderate, and severe ASD groups. The research shows promise for developing personalized diagnosis and treatment based on severity, which could help tailor interventions for those on the autism spectrum. However, limitations include a small dataset, lack of independent validation, and testing of only one machine learning model. Further research with larger sample sizes, multi-site studies, and evaluation of different algorithms is needed to strengthen findings and validate the approach before clinical implementation[18] .

The article in [19] proposes an automated technique for diagnosing Autism Spectrum Disorder (ASD) using resting-state fMRI data and the elastic net model, which improves efficiency by not requiring prior feature selection. The research addresses limitations of previous works, such as high-dimensional data and overfitting risks, while aiming to identify valid biomarkers for automated ASD diagnosis. Using the Autism Data Exchange (ABIDE) database, the study shows potential for contributing to early diagnosis and intervention for ASD. Future research could focus on larger, more diverse datasets and exploring advanced machine learning techniques or combining multiple biomarkers to improve diagnostic accuracy.

The study in [20] proposes a deep learning approach to analyze brain networks for ASD diagnosis, demonstrating superior classification accuracy compared to traditional machine learning algorithms. Using the Autism Brain Imaging Data Exchange (ABIDE) dataset, the research aims to provide an accurate and efficient diagnostic method for early intervention and personalized ASD treatment. The study's significance lies in its potential to overcome limitations of traditional diagnostic techniques. Future research could focus on applying deep learning to larger, more diverse datasets and investigating ASD's underlying neural mechanisms using functional brain networks.

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In [21], the authors explore the use of machine learning and deep learning techniques to classify and diagnose autism spectrum disorder (ASD) using structural MRI data, aiming to overcome limitations of traditional diagnostic methods. The research utilizes the Autism Brain Imaging Data Exchange (ABIDE) dataset to develop an accurate and efficient diagnostic technique for early ASD detection and intervention. It highlights the potential of sMRI to provide insights into ASD-related cognitive abnormalities. Future research could focus on applying deep learning methods to larger datasets and investigating ASD's underlying neural mechanisms using brain networks.

The study in [22] provides an overview of fMRI findings in autism spectrum disorders (ASDs), highlighting consistent patterns of hypoactivation in "social brain" areas and aberrant activation in front striatal regions during cognitive tasks. These findings contribute to our understanding of ASD pathology and provide insights into its pathogenesis. The research has implications for developing etiological models and targeted therapies for ASD. Multiple datasets were used in this analysis, offering a comprehensive view of ASD neuroimaging findings.

The research in [23] integrates resting-state fMRI data to achieve high classification performance for Autism Spectrum Disorder (ASD) diagnosis using machine learning techniques. This research reflects the growing interest in using fMRI data and advanced analysis methods for ASD diagnosis. The paper's significance lies in its potential to improve ASD diagnostic accuracy, enabling earlier intervention and treatment. This study reviews 45 research papers, indicating a broad range of research on this topic and using diverse datasets.

In [24] the paper introduces a novel method for diagnosing ASD using fMRI data, based on a hierarchical repeated-variance encoder (HRVAE), achieving 82.1% accuracy. The study utilizes the ABIDE dataset and potentially contributes to understanding functional brain networks (FBNs) in ASD. While weaknesses are not explicitly stated, addressing these could enhance the methodology. Future research could apply this method to other brain disorders and further explore sequenced integrated FBNs.

The research in [25] proposes a classification algorithm for autism spectrum disorder (ASD) diagnosis using structural MRI and deep convolutional neural networks, achieving superior accuracy compared to state-of-the-art methods. The study emphasizes the importance of early ASD identification and demonstrates the effectiveness of sMRI for detecting brain pathology. Using a dataset of 484 ASD subjects and 491 controls, the proposed model with various optimizers achieves high accuracy at different data partition ratios. Future work could compare this method with others across multiple sites and explore other imaging modalities to further improve ASD diagnosis accuracy.

Despite the ability of MRI to identify subtle brain pathologies associated with ASD, several factors limit its use as a diagnostic tool MRI image interpretation is complex and expertise-intensive, making it difficult to carry provide, validate and implement in clinical settings.

1.3. Autism Early Detection based on Whole Exome Sequence Testing

Whole-exome sequencing (WES) is a genomic technique that sequences all protein-coding regions of genes, used to identify potential genetic biomarkers for autism spectrum disorders (ASD). While not a direct brain imaging method, WES has shown promise as an accurate and sensitive initial diagnostic test for ASD, particularly for inherited causes. However, interpreting the significance of identified genetic variants remains challenging, as not all variants affect health. The relationship between genetic changes identified by WES and their impact on ASD is still being investigated[26,27].Whole genome analysis of more than 500 ASD cases and family members offers innovative understandings of the genetic basis of Autism.

In [28] the study explores the role of rare non-coding variants in autism susceptibility, using a sophisticated analytical system to compare potential associations between variants and ASD.

The research finds a stronger association with coding regions compared to non-coding variations, suggesting a small but significant role for non-coding variants in autism spectrum disorders. The study emphasizes the need for large, well-phenotyped cohorts and rigorous methods in genome-wide sequencing research to improve results. These findings contribute to our understanding of ASD's complex genetic architecture and highlight the importance of further large-scale genomic studies.

The paper in [29] investigates the genomic factors of Autism Spectrum Disorder (ASD) through whole genome sequencing of over 500 ASD cases and families, focusing on the role of rare non-coding variants. Using an advanced analytical framework, the research found stronger associations with coding regions compared to non-coding variations, suggesting a minor but potentially significant contribution of non-coding variants to ASD. The study emphasizes the need for large, well-characterized cohorts and rigorous statistical methods in whole genome sequencing research. These findings provide a foundation for further genomic studies to deepen our understanding of ASD's genetic architecture.

In[30] the paper provides a comprehensive review of recent advances in genetic engineering and functional research that contribute to our understanding of autism spectrum disorders (ASD).

Furthermore, the paper highlights and suggests limitations of functional imaging in ASD research to identify neuron-specific functional networks and While the focus of the paper is primarily on genetic and functional studies, future research directions could examine other aspects of ASD pathogenesis to gain an understanding of the disorder which is in-depth.

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The article [31] provides important insights into understanding the structural and functional basis of autism spectrum disorders (ASD) through the integration of genomic and neuroscientific data. ASD Identification of two unique risk factors that characterize different forms of ASD and risk factors for serious disability. As reported in an internet search, biological and environmental factors act in different ways to influence the nature of ASD and reinforce its role. The specific neuronal network proposed in the paper presented by Going forward remains to identify the contributing genes and the rest. Molecular pathways that use large numbers such as SSC to find new therapeutic targets as proposed down the road.
This authors in [32] explores the genetic and neural basis of autism spectrum disorders (ASD) using genetic and brain data. The authors identify complex genetic factors and call for new tissue-specific models. Their findings highlight the need for further research into genetic and molecular mechanisms for potential therapies. While this study focuses on genetics and neuroscience, future research should consider psychosocial factors for a more comprehensive understanding of ASD.
In [33] the study explores the genetic and neural basis of autism spectrum disorders (ASD) using genetic and brain data. The authors identify complex genetic factors and call for new tissue-specific models. Their findings highlight the need for further research into genetic and molecular mechanisms for potential therapies. While this study focuses on genetics and neuroscience, future research should consider psychosocial factors for a more comprehensive understanding of ASD.
In [34] The Sultan Qaboos University Hospital in Oman established a Department of Developmental Pediatrics to improve early diagnosis and intervention for children with developmental disorders. Collaboration with the Department of Genetics emphasizes understanding the genetic basis of these conditions. This multidisciplinary approach, involving healthcare professionals from various backgrounds, has the potential to significantly improve identification, treatment, and outcomes for children with developmental disorders.
The study in [35] sequenced the whole genome in over 1,000 ASD families, identifying 7 novel and 74 total risk genes. Increased mutations in known risk genes suggested a pleiotropic effect. Interestingly, common genetic variants from unaffected parents may contribute to ASD risk alongside rare mutations. This highlights the complex interplay of genetics in ASD.

A large-scale WGS study in[36] of over 11,000 individuals with ASD identified rare mutations and sheds light on the complex genetic architecture of the disorder. This comprehensive dataset (Autism Speaks MSSNG) serves as a valuable resource for future research into personalized therapies for ASD.
Valuable insight is provided into the genetic basis of autism spectrum disorder (ASD) through detailed analysis of whole-genome sequencing data from a large cohort through more than 11,000 individuals with ASD and their family on the examined members, researchers found ASD in a significant portion of context in [37] . We were able to identify rare associated genetic alterations and these strains had a wide range of mutations. This elucidates the complex genomic regulation underlying ASD and sheds light on potential causative factors.
The study identified a wide range of genetic mutations in ASD, highlighting the complex genetic basis of the disorder. Collaborative efforts to analyze this data hold promise for developing personalized therapies. However, more research is needed to fully understand ASD. This study highlights whole-exome sequencing (WES) as a powerful tool for early detection of ASD in children, offering faster and more accurate results than traditional methods. While WES can identify rare conditions and inform treatment, limitations exist in capturing all genetic variations. Despite this, WES presents a valuable research approach with the potential to improve ASD diagnosis and outcomes.

1.4. Autism Early Detection based on Eye Tracking

Eye-tracking technology measures eye movements to assess gaze patterns in individuals with autism spectrum disorder (ASD). This non-invasive method is particularly useful for studying young children and has revealed differences in social attention processing compared to typically developing individuals. Eye-tracking data offers valuable insights into the neurocognitive mechanisms underlying social cognition in ASD[38] .
In [39] the study explores eye-tracking technology for evaluating Autism Spectrum Disorder (ASD), particularly in young children. By visualizing eye movement patterns, the research aims to develop prognostic tools using image-based methods. The publicly available dataset of eye-tracking data and images can support further research into ASD diagnosis and development of predictive models. This highlights the potential of eye-tracking as a valuable tool for ASD assessment.
In [40] authors propose a method for analyzing ASD using eye-tracking visualizations. While short video clips might limit captured movements, the approach holds promise for computer vision-based ASD assessment. Future research should explore longer recordings and integrate eye-tracking data with other modalities for a more comprehensive understanding of ASD.
The study in [41]utilizes unsupervised machine learning to identify subgroups within ASD based on eye-tracking patterns. The model analyzes compressed data learned by a deep autoencoder. Promising initial findings suggest this approach can reveal distinct gaze behaviors in individuals with ASD. This research highlights the potential of AI in analyzing eye-tracking data for a deeper understanding of ASD.
The research in [42] explores emerging neuroimaging (MRI, EEG, fNIRS) for early ASD detection in high-risk infants by identifying abnormal brain development and activity. This

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objective approach has potential to surpass limitations of current methods, but further research is needed to address weaknesses, broaden study scope, and validate these techniques in wider ASD populations

In [43], an NLP technique for early ASD diagnosis was proposed. It addresses limitations by converting eye-tracking data into interpretable text for NLP analysis. Initial results show promise for extracting meaningful features and achieving high classification accuracy. However, limited data size restricts generalizability. Future work should explore larger datasets and address practical challenges of eye-tracking implementation.

The article in [44] proposes a novel approach for early ASD diagnosis using machine learning and NLP to analyze eye-tracking data. It represents eye movements as text sequences, achieving high accuracy (0.84 ROC-AUC) in feature extraction and classification. While validation on larger datasets is needed, this interdisciplinary work highlights the potential of NLP and machine learning to revolutionize ASD diagnosis and improve outcomes.

A floor-breaking approach for early Autism Spectrum Disorder (ASD) diagnosis is provided in[45] this study explores using machine learning and NLP to analyze eye-tracking data for early ASD diagnosis. It represents eye movements as text, enabling feature extraction and achieving promising classification accuracy. Further validation on larger datasets is needed, but this work highlights the potential of AI for more objective ASD diagnosis and earlier intervention.

In [46]a study (building on prior work) utilizes machine learning and NLP to analyze eye-tracking data for early ASD diagnosis. It overcomes limitations of past methods by representing eye movements as text, enabling feature extraction and achieving high classification accuracy (0.84 ROC-AUC). While larger datasets are needed for validation, this approach highlights the potential of AI for more objective and data-driven ASD diagnosis.

This study proposes a novel method for early ASD diagnosis using machine learning and NLP to analyze eye-tracking data. It converts eye movements into text sequences, overcoming limitations of past methods. Initial results using convolutional neural networks show promise but require validation on larger datasets. This interdisciplinary work highlights the potential of AI for more objective ASD diagnosis.

1.5. Autism Early Detection based on Facial Expressions

Facial expressions play a key role in social interaction, but individuals with Autism Spectrum Disorder (ASD) often struggle to interpret and respond to them. They may exhibit atypical expressions, limited eye contact, and focus on facial details, hindering their ability to understand emotions and navigate social situations. This difficulty can limit their ability to form meaningful relationships[47].

The study in[48] explored facial expression recognition in ASD using tasks with varying complexity. Individuals with ASD showed lower accuracy and slower response times compared to controls, but some performed within the typical range. These findings suggest facial expression recognition difficulties as potential biomarkers for ASD, highlighting the need to assess their prevalence and severity.

The meta-analysis in [47] the study examines facial expressions in individuals with ASD compared to controls. Individuals with ASD showed atypical expressions and processing of facial emotions. These differences were influenced by participant characteristics and task variations. The study highlights the need for further research on atypical facial expressions in ASD.

The researchers in [49] compared facial expression recognition in ASD and typically developing individuals. Those with ASD showed lower accuracy and slower reaction times. However, some within the ASD group performed typically, highlighting the disorder's heterogeneity. This emphasizes the need to move beyond group comparisons and assess individual differences in facial expression processing within ASD.

The authors in [50] investigated emotion recognition in ASD using an online platform. Compared to a control group, individuals with ASD showed difficulties identifying emotions. This challenges the notion that ASD only affects verbal communication. The findings support the development of interventions to improve social skills in ASD.

Another research in [51] explores how facial expression differences between autistic and neurotypical individuals impact social interactions. It highlights the need to consider these differences in clinical assessments and interventions. Understanding these variations can pave the way for improved communication and support for individuals with autism spectrum disorder (ASD).

Investigation of facial emotion recognition in individuals with autism spectrum disorder (ASD) is important for understanding the specific challenges this population faces in social interaction.

This study explores using CVA for facial expression analysis in a tablet-based ASD assessment. This non-invasive method offers promise for early detection and objective assessment. While feasible, the small sample size requires further research in broader settings and populations. These findings hold promise for developing technology-based interventions for ASD [52].

In [53], the study investigates deep learning for facial expression analysis in ASD detection. It aims to improve diagnosis accuracy and efficiency through a non-invasive, early detection method. This approach has the potential to reduce diagnostic burden and improve outcomes for individuals with ASD and their families. Further research is needed to validate this approach.

The importance of the paper [54] identified subgroups within ASD with distinct facial expression recognition patterns and brain activity. These findings suggest potential for subgroup-specific interventions to improve social interaction and well-being in individuals with ASD. The research highlights the

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importance of considering individual differences when designing interventions for ASD. in this subgroup[55]. This study proposes video game-based facial expression analysis for ASD detection in young children. Using a CNN model, they achieved 92.3% accuracy, highlighting the potential of video games for capturing behavioral data. Early detection through this method could improve outcomes for children with ASD and their families. Future research should explore contextual and cultural factors influencing facial expression recognition in ASD[52].

The results showed that individuals with ASD showed high accuracy significantly lower and longer reaction times compared with typical developers and fewer individuals performed in the normal range. In addition, future research could examine the effects of different intervention strategies to improve facial expression recognition in individuals with ASD, contributing to social interaction and communication skills development.

1.6. Autism Early Detection based on Behavior Coding Measures

Functional Behavior Assessment (FBA) is an important evidence-based practice in Applied Behavioral Assessment (ABA) that aims to identify the causes of challenging behaviors in children with autism spectrum disorders (ASD) . This type of research plays an important role in identifying interventions, allowing for targeted interventions and the use of positive motivational strategies to promote behavior change. Finally, FBAs help improve children with autism’s participation in activities and overall quality of life[56].

In [57] the study emphasizes the need for research on the impact of languages on language learning in bilingual children with ASD. Existing literature offers conflicting results, with some studies finding similar language development in bilingual and monolingual children and others reporting delays. The paper highlights the lack of evidence supporting limiting language exposure for these children. This study proposes using computer vision and machine learning to measure behavioral markers in ASD, addressing limitations of subjective clinician assessments.

The approach [58] offers standardized, objective measures in natural settings and has the potential for early intervention and deeper understanding of ASD. Future research could explore integrating other data types for a more comprehensive assessment.

The paper in [56] investigates a Parent-Therapist Directed (PRT) program for young children with ASD. The intervention combined parent training with therapist-directed treatment, leading to significant improvements in language, vocabulary, and social interaction. This approach shows promise for improving social skills in young children with ASD and highlights the benefits of parent involvement in treatment.

In [59] compared listening behavior in verbal ASD and typically developing individuals. Those with ASD showed lower accuracy and slower response times, but some performed typically. While promising for identifying listening deficits in ASD, the study's limitations include a small sample size and lack of a control group. Future research should address these limitations and explore interventions targeting auditory processing in ASD.

The research in [60] examines differences in camouflage and compensation among youth with autism spectrum disorders, focusing on gender-based differences and compensation behavior Camouflage refers to the way individuals with ASD, especially females , burial or covering their symptoms in a social situation seems to be better than the women who have seen the women who have found it often do participants with higher rewards exhibit stronger social interaction behaviors than do participants with lower rewards Franz and et.al.[61] provide an overview of research on early intervention for very young children at high risk for autism spectrum disorder (ASD).

It emphasizes the importance of early intervention to improve long-term outcomes and emphasizes the need for global programs and services to support children with developmental disabilities. The paper discusses the role of parental involvement in interventions and identifies several systematic reviews and meta-analyses assessing the effectiveness of various interventions for children who forming ASD. This study emphasizes the importance of early intervention for ASD but doesn't specify data used. It reviews the impact of Applied Behavior Analysis (ABA) on various outcomes in children and youth with ASD.

While positive effects were found in most categories, limitations include small sample sizes and lack of comparison with other interventions. Future research should address these limitations to provide stronger evidence for ABA's effectiveness[62].

In [63] the paper highlights the importance of transparent reporting of researcher characteristics, including those with ASD and bilingual experiences. It emphasizes the need for acknowledging multilingualism and dispelling misconceptions about bilingualism in ASD. Future research should explore the interaction between ASD and bilingualism to develop effective support for bilingual individuals with ASD.

A recent study by the University of Southern California and Children’s Hospital Los Angeles in[64] investigated sensory desensitization using SADE during dental procedures for autistic children. Children experienced significantly less stress with SADE compared to a regular procedure. SADE appears to be a safe and effective method for reducing anxiety and improving dental experiences in children with autism, potentially improving their overall oral health.

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In[65] the study proposes an automated method to analyze social gaze behavior in children with ASD during therapy. Social gaze is important for social interaction, and children with ASD often struggle with it. The method uses deep learning to analyze gaze patterns in therapy videos. This approach could be used to assess social behavior in various contexts and improve future research. This study proposes a deep learning method to assess social gaze in children with ASD during therapy. Social gaze is important for social interaction, and children with ASD often have difficulties. This offers a tool for treatment evaluation but has limitations like small sample size. Future research could explore broader applications and integrate other data for a deeper understanding of social processes in ASD.

1.7. Autism Early Detection based on Blood Biomarkers

Blood-based biomarkers hold promise for early ASD detection. Researchers are exploring specific molecules and genetic markers to identify patterns indicative of ASD risk or presence. Advanced technologies like genomics are used, aiming for simple tests that integrate into clinical practice. However, large-scale studies are needed to validate these biomarkers for diverse populations[66].

This study in [67] investigated blood acyl-carnitine levels and intelligence in Chinese children with ASD. Children with ASD showed lower levels, suggesting potential mitochondrial dysfunction and abnormal fat metabolism. These findings warrant further research into potential metabolic causes of ASD. The study included 60 children with ASD and needs validation with larger datasets.

This review summarizes research on various potential biomarkers for ASD, including physiological, genetic, and metabolic markers. These could enable earlier diagnosis and intervention. Some biomarkers may even predict treatment response. Studies like CAMP identified abnormalities suggesting specific metabolic biomarkers. Overall, biomarkers hold promise for improving ASD diagnosis, prognosis, and treatment. Frye and et.al. in [68] analyze the financial costs and emotional burdens of caring for individuals with ASD. It highlights the impact on caregivers' well-being and society. While limitations exist in prior research, future studies could explore cost-effective interventions, long-term economic outcomes for individuals with ASD, and caregiver support strategies. In [69], the review highlights the need for reliable biomarkers for ASD diagnosis. It explores advances in genetics, proteins, and metabolites as potential markers. While no single biomarker exists, research has improved understanding of ASD's complexity. Future directions include exploring additional omics approaches and personalized therapies based on biomarker profiles.

This review explores recent research on genetic, immune, and protein biomarkers for ASD detection and treatment. While no single biomarker exists, these approaches hold promise for earlier diagnosis and tailored interventions. Future research could examine gene-environment interactions and the effectiveness of biomarker-targeted interventions[70].

This study explores blood protein biomarkers for early ASD diagnosis. Combining computational analysis and experiments, researchers identified potential protein candidates. These findings hold promise for earlier detection and improved outcomes for individuals with ASD, but further validation is needed[71] .

Jensen et al.[72] This review emphasizes the need for objective biomarkers for ASD diagnosis and treatment. It explores various potential markers including genetics, proteins, and immune function. Biomarker development is ongoing, highlighting the importance for early intervention and treatment tailoring. However, limitations include lack of control groups and the need for further validation.

The study in [73] investigated blood proteins as biomarkers for ASD diagnosis (91 ASD, 30 controls). Machine learning identified 15 potential protein biomarkers. Further validation is needed, but these findings show promise for objective ASD diagnosis. Autism spectrum disorder (ASD) affects approximately 2% of children in the United States and early diagnosis and treatment in[74] highlights the potential of blood proteins as biomarkers for ASD diagnosis. Proteomics and machine learning approaches are promising for identifying protein signatures. Early diagnosis is crucial for better outcomes in ASD, but current methods have limitations. Further research is needed to validate these potential biomarkers.

A recent study used proteomic analysis to compare plasma protein profiles of children with ASD and typically developing children and identified 45 proteins expressed in uniquely associated with processes Multiple Reaction Monitoring (MRM). Using machine learning and verification, the researchers identified two proteins, biotinidase and carbonic anhydrase 1, as potential early detectors of ASD. This information provides valuable insights and potential biomarkers for the early diagnosis of ASD[75]. Blood-based biomarkers hold promise for earlier ASD diagnosis and intervention. Advanced technologies like genomics are being explored to identify these markers. While promising for improved diagnosis and treatment, further research is needed to validate proposed methods and explore their long-term effectiveness.

1.8. Autism Early Detection based on Urine Analysis

Urine testing is being investigated as a potential early detection tool for ASD. Studies suggest differences in urine metabolites between children with and without ASD. However, more research is needed to confirm these findings and establish urine analysis as a reliable diagnostic tool [76] .

This study explores the link between GI problems and behavior in children with ASD. It examines the effects of a combined dietary approach and prebiotics on gut health and behavior. Children showed reduced GI symptoms and improved behavior. This suggests a potential benefit for managing ASD symptoms through dietary interventions[77].

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The lack of specific laboratory tests for early detection of autism spectrum disorder (ASD) is a major challenge in this field. However, in[76] the study investigates urinary amino acids (UAAs) as potential biomarkers for ASD. Researchers compared UAA levels in children with ASD to typically developing children. Specific UAA metabolites were identified as biomarkers. However, larger studies are needed to confirm these findings for earlier ASD detection and intervention.

In [78] a study explores potential physiological biomarkers for ASD using urine samples. Gas chromatography and machine learning techniques identified specific urinary organic acids that differed between children with and without ASD. These findings offer insights into ASD development and potential interventions but require validation with larger studies. The authors in [79] compared urine composition in children with ASD, their mothers, and typically developing children. It identified differences in metabolite excretion, suggesting potential links to mineral metabolism in ASD. The findings warrant further research with larger, controlled studies to explore dietary interventions for ASD Endocrine abnormalities in children with autism spectrum disorders are the focus of this article[80] compared urine and blood samples from 30 children with ASD to 30 controls. Analysis revealed metabolic differences, suggesting potential biomarkers for ASD. However, limitations include a small sample size and lack of dietary control. Further research with larger, controlled studies is needed. This meta-analysis found differences in trace elements like barium and copper in children with ASD compared to controls. These imbalances may contribute to ASD development. However, limitations include a small number of studies and the need for further research to confirm these findings and explore potential treatment strategies[81].

The aim of the systematic review and meta-analysis in[82] is to examine the link between chromium exposure during pregnancy and cognitive problems in children. No significant association was found, but limitations like small sample sizes and a lack of standardized measurements were identified. Further research with larger, more standardized studies is needed. Metabolomic studies suggest abnormal metabolite levels in ASD, potentially indicating underlying biological issues. These findings may lead to biomarkers for early diagnosis and targeted interventions. Research has explored various biomarker types, including physical, neurological, and behavioral markers. Understanding these physiological differences could be crucial for earlier ASD diagnosis and intervention[83].

In [84] the study explores organic acid testing as a potential diagnostic tool for ASD using urine samples. It identified differences in organic acid levels between ASD and control groups. These findings may improve understanding of ASD and aid in developing diagnostic tools. However, further research is needed to confirm these results.

The article in [85] discusses urinary pteridines (neopterin and biopterin) as potential biomarkers of inflammation in ASD. Higher neopterin levels suggest immune system involvement in ASD. These findings warrant further research into the specific immunological mechanisms and long-term changes in these markers in ASD. The study included 212 ASD patients and 68 controls.

The review [86] This study explores blood protein biomarkers for ASD diagnosis using a larger sample size and advanced technology. It identified immune and gut-related proteins linked to ASD. However, limitations include lack of longitudinal data and validation across age groups. Further research is needed to confirm these findings and explore protein function in ASD. Urine tests and dietary interventions are explored for potential roles in ASD diagnosis and management. Urine metabolite and amino acid profiles show promise as biomarkers but require further validation. Gastrointestinal dysfunction in ASD suggests dietary interventions may improve symptoms and well-being. Despite progress, specific laboratory tests for early ASD detection remain elusive.

1.9. Autism Early Detection based on Vision Screening

Vision analysis using eye movement tracking shows promise for early ASD detection. This objective method complements traditional assessments and could improve access to screening, particularly for underserved populations. Further research is needed to refine these methods for wider implementation[87]. In[88] This study explores a machine learning approach for early ASD detection using parent questionnaires and home videos. Two algorithms were trained, one for each data source, and then combined for improved accuracy. This method offers promise for ASD detection outside clinical settings, potentially improving access to early intervention. However, larger studies are needed for validation.

The paper in[87] investigates a machine learning method for early ASD detection using parent reports and video analysis. It combines data sources to improve accuracy and offers potential for home-based testing. However, the study was small and larger trials are needed for validation. This approach could revolutionize early intervention for ASD. In[89] the study explores using facial image analysis with deep learning for early ASD detection. The YOLOv8 model achieved promising results, suggesting potential for non-invasive screening. However, limitations include the small sample size and lack of comparison to existing methods. Further research is needed to validate and refine this approach. Applying AI, ML and IoT technologies in [90] uses facial images, multi-source data analysis, and wearable sensors hold promise for earlier ASD diagnosis and personalized interventions. However, limitations include the need for validation in real-world settings. Further research is needed to refine these methods. The authors in [45] study investigates eye-tracking combined with machine learning for early ASD detection.

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Deep learning models analyze eye movement data to identify potential autism cases. This non-invasive approach shows promise for improving early diagnosis but requires further validation.
In[91] AI, ML, and IoT technologies offer potential for ASD diagnosis and management. Machine learning analyzes facial features, eye-tracking data, and behavior for earlier detection. Integration with wearable sensors allows for personalized interventions and improved quality of life for individuals with ASD. The use of AI, ML and IoT technologies has the potential to revolutionize the field of autism detection and management in [92]. AI, ML, and IoT technologies hold promise for ASD diagnosis, intervention, and management. Machine learning analyzes data like facial features and medical claims to detect ASD and personalize interventions. Wearable sensors allow for continuous monitoring. These advancements have broader implications for improving healthcare across various conditions.
In [93] the study explores using AI, machine learning, and IoT for ASD. The goal is to improve screening accuracy, personalize interventions, and enhance quality of life for individuals with ASD and their families. This approach has the potential to revolutionize early detection and overall, ASD management.
In [94], has AI, ML, and IoT for ASD detection and management. It aims to improve screening accuracy, personalize interventions, and enhance quality of life. Wearable sensors allow for continuous monitoring, potentially leading to earlier detection and better outcomes. This approach has broader implications for personalized medicine across neurological disorders. The researchers in [95] explore a machine learning system to assess name response in children for potential ASD detection.

The system showed promise as a tool, but further research is needed for validation and to determine its role alongside existing methods. The study highlights the need for controlling bias and comparing with existing tools.
The importance of the research [96] is using machine learning to assess name response in children for ASD detection. The approach shows promise but needs validation and comparison to existing methods. Controlling for bias in the dataset and including a broader population are important next steps. Machine learning and computer vision offer a promising, objective approach for early ASD detection. This method complements traditional assessments and could improve access to screening, particularly for underserved populations. Further research is needed to refine these methods for wider implementation.

1.10. *Autism Early Detection based on Nervous Oscillation*

EEG/MEG studies show brain wave differences between ASD and typically developing individuals. Altered neural connectivity is suggested, but further research is needed to confirm the reliability of neural oscillations as an ASD screening tool[97].
The current study used resting state electroencephalography (EEG) data from 15 ASD subjects and 18 TD controls to examine longitudinal correlations of electrocortical oscillations within the ASD group. This may include unstable neural states and electrocortical fluctuations of cognitive dysfunction.
The aim of the study[98] was to examine motor-related brain activity in ASD using MEG. Age-related changes were observed in both ASD and control groups. However, a specific motor response (PMBR) differed in older ASD children. Considering age is crucial for interpreting brain activity in ASD research. Espenhahn and et.al. [97] investigated tactile processing in young children with ASD using EEG. They compared brain responses (SEPs) between autistic and typically developing children. This approach may help us understand sensory processing problems in ASD, but the small sample size and inclusion of children with multiple diagnoses require further research. The study consisted of 33 children with autism and 45 age- and gender-matched children. To improve the paper, the sample size could be increased, and the study focused on specific subgroups of children with autism. Future directions include exploring other cognitive strategies, testing interventions targeting cognitive challenges and examining the long-term outcomes of early intervention in cognition of both response and progress.
The study[99] was introduced for providing specifics of the proposed rTMS protocols, including stimulation site, frequency and duration, as well as additional empirical studies to demonstrate the efficacy and safety of rTMS that in addition to the treatment of ASD, the paper would benefit from a detailed analysis of related literature any existing work. This article examines neurological changes in individuals with tuberous sclerosis complex (TSC) and their connection to autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD). It investigates oscillatory interactions in neuronal activity, revealing that TSC is associated with hypo connected neural networks across cognitive tasks. The research in [100] finds that ASD symptoms correlate with hypoconnectivity and reduced network organization, while ADHD symptoms relate to hyperconnectivity in specific tasks. Using data from the Tuberous Sclerosis 2000 (TS2000) study, the paper provides insights into neural changes in TSC and their relationship to ASD and ADHD, despite limitations like small sample size.
The authors in [101] explore abnormal physiological eye responses (dilation, contraction, twitching) in individuals with ASD during emotional faces tasks. It aims to explain reduced eye movements in ASD independent of emotion perception. The comprehensive analysis using controlled stimuli offers insights into unique eye movement patterns and the physiological basis of facial recognition difficulties in ASD, paving the way for future interventions.

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In[102] Brain activity during visuomotor tasks was compared in children with ASD and typically developing children using magnetoencephalography. This study revealed differences in brain activity patterns, suggesting potential neural markers for ASD. However, the limited sample size and focus on children restrict the generalizability of the findings. Future research could investigate broader populations and explore connections to other psychological aspects. The article[103] explores emotional processing in the brain using ERSP and its impact on cognition. It investigates how ASD may influence emotional perception and proposes a Bayesian framework for understanding ASD cognition. While offering insights into sensory processing and brain activity, limitations include variability in EEG/MEG data and the need for larger samples. Further research is needed to refine the use of neural oscillations for ASD diagnosis.

1.11. Autism Early Detection based on Gender Types

Sex-based early diagnosis of autism is an area of intense research and clinical interest. The study highlighted the impact of gender stereotypes and expectations on autism recognition in girls.

Furthermore, gender differences examined in clinical populations detected ASD later in young girls, emphasizing its importance and the need to improve early detection methods. Males are more likely to be diagnosed with autism than females[104].

In[105] This research explores using eye-tracking and machine learning to analyze visual attention in autism, aiming for a more objective diagnosis. This could pave the way for autism screening. However, the specific data used, and limitations of prior work aren't addressed. Future work can delve deeper into these aspects and explore potential treatments. This study proposes an ANN model for diagnosing autism spectrum disorder (ASD), achieving 100% accuracy with an ASD screening app dataset. It highlights the potential of ANNs in various diagnoses. While promising, the specific data and limitations of prior work are not addressed. Future research could explore other machine learning methods, the impact of input parameters, and the model's generalizability[106].

The work in [104] explores how gender bias impacts perception of autism symptoms, particularly underdiagnosis in girls due to stereotypical expectations. Using an online parent model, it highlights the role of gender in symptom assessment. This research can improve early intervention for all autistic individuals, especially girls. Future work should incorporate broader samples and consider a wider range of behaviors.

The study [107] investigates the low autism acceptance among female primary school teachers, revealing a bias towards recognizing autism in boys. This highlights the need for training to improve identification of girls with autism and address underdiagnosis in women. In[108] the study investigates the link between autism and gender identity in transgender and gender-diverse populations using online surveys. It explores whether this group experiences higher rates of autism and associated traits. The findings could improve our understanding of autism and gender, but the use of online samples limits generalizability. Future research with more diverse samples is needed. In [109], the researchers propose an XAI (explainable AI) model for early autism detection in children. It highlights the limitations of past black-box models and the benefits of interpretability in healthcare AI. Using an SVM approach, the authors demonstrate a more transparent model for ASD classification, potentially improving diagnosis and treatment for children with autism. The paper [110] addresses the problem of low acceptance of autism by women, especially primary school teachers. It discusses how gender stereotypes and misunderstanding of the female autism phenotype contribute to this diagnosis. Previous work has shown that autistic women have a diagnostic bias, but the underlying mechanisms are poorly understood. The paper proposes an approach using vignettes.

The research in[111] focuses on examining the stress experienced by individuals with autism spectrum disorders in various situations, emphasizing the importance of understanding their specific environmental perceptions in terms of order emphasize habitat care.

The authors surveyed individuals with ASD using a questionnaire to collect information about comfort preferences and found that sound affected their stress levels significantly, while thermometer, indoor perceivable air quality (IAQ) and stress factor sensitivity to a higher level. This study investigates how environmental factors, like sound pitch, impact stress in individuals with ASD. It highlights the need for design guidelines that consider these sensory sensitivities to improve well-being in ASD spaces. Future research should explore environmental influences on recovery for individuals with ASD.

The study [112] proposes a new method using FMCDM technology to classify patients with autism spectrum disorder (ASD) based on their competencies. They analyze data from 42 patients and categorize them into different severity groups. This method highlights the potential of FMCDM for early diagnosis of ASD. While the study [113] explores using FMCDM to diagnose and categorize ASD severity in toddlers. They analyze clinical and sociodemographic data to classify patients into mild, moderate, and severe groups. The method shows promise for early ASD diagnosis using FMCDM, highlighting its potential for patient evaluation. This work highlights limitations in current autism research. While sex-based screening is crucial, existing studies often lack focus on cultural influences and underrepresent gender differences in identification and diagnosis. Future research should address these gaps to improve autism diagnosis across populations.

1.12. Autism Early Detection based on The Influence of Social Media

This work explores using social media and digital apps to identify autism symptoms and overcome diagnosis barriers.

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It highlights the potential of online tools for early diagnosis in vulnerable populations, while acknowledging the need for expert guidance. The study also emphasizes the importance of biological markers for a deeper understanding of autism[114].

The research study in [115] proposes an fMCDM-based method for ASD diagnosis and severity classification. Analyzing data from nearly 1000 patients, it identifies 19 key factors and categorizes patients into mild, moderate, and severe groups. This highlights the potential of fMCDM for early ASD diagnosis. In [114] the study explores how social media fuels unverified health claims, focusing on the vaccine-autism debate. Analyzing social media data across three countries, it reveals variations in online discussions. The findings highlight the need to understand social media's role in spreading health information and can inform public health strategies to combat misinformation.

The paper [116] explores digital media use in children with ASD, considering its potential benefits and risks for development.

It emphasizes the need for understanding how ASD-specific traits interact with digital media. The findings can inform clinical practice by providing guidance on managing media use to support healthy development in children with ASD. This study examines how autistic individuals utilize Facebook-like online support groups. It analyzes user interactions and information sharing within these groups. By understanding user perspectives, the research offers valuable insights for improving patient communication and informing clinical practices. Ultimately, this can benefit both patients and healthcare professionals[117].

This case highlights the need to fight COVID-19 misinformation on social media. It proposes a new method (SISM) for analyzing social media content to identify fake news. SISM aims to overcome limitations of existing methods by considering diverse information sources and user influence. This could empower public health professionals to develop more effective anti-misinformation strategies[118].

This paper [119] explores the link between early digital media use, parent-child interaction, and ASD-like symptoms. They find increased screen time and less caregiver play at 18 months correlate with more ASD-like symptoms, but not diagnosed ASD. These findings highlight the potential impact of early experiences and warrant further research. However, the paper [120] explores experiences of non-autistic partners in online autism support groups, highlighting a gap in research. Understanding their perspectives can improve support and relationships. While relying on self-reported data has limitations, the study emphasizes the need for further research on this understudied group.

The study[121] explores the link between social functioning, social media use, and consumer behavior in autistic individuals. They use a social activity measure (QoSF) to show how social activity impacts social media usage and consumer behavior. These insights can help marketers better understand autistic consumers and improve their online experiences.

The research paper [122] explores social media use in autism, highlighting its potential for communication and social connection. However, the impact on mental health, relationships, and work needs further exploration. Criticizing past research methods, it emphasizes the need for high-quality studies to inform interventions and support services promoting positive online experiences for autistic individuals. This review examines the limited evidence on social media interventions for autism. While highlighting potential benefits, it critiques the lack of high-quality studies on specific use cases. The paper emphasizes the need for further research to explore the effectiveness of social media interventions for individuals with ASD[123].

1.13. Autism Early Detection based on Electroencephalography (EEG) and magnetic resonance imaging (MRI)

Combining EEG (electrical activity) and MRI (brain structure) offers a powerful tool for understanding autism. This approach provides a comprehensive view of brain function and structure in autistic individuals. By analyzing both signals simultaneously, researchers can link abnormal activity to specific brain regions. This deeper understanding can improve autism diagnosis and reveal the underlying neurobiology of the disorder[124].

This work investigates the link between brain structure and function in humans using combined EEG/fMRI or diffusion MRI. It reviews studies that explore this connection and highlights the growing interest in using machine learning with fMRI data to diagnose Autism Spectrum Disorder (ASD). This approach offers promise for improving ASD detection by understanding the relationship between brain structure and function[124].

The study in [125]proposes This study proposes a new deep learning method (HRVAE) using fMRI data to identify autism spectrum disorder (ASD). It outperforms previous methods in accuracy by identifying hierarchical functional brain networks. The findings contribute to understanding brain network hierarchy in ASD and have potential applications for other brain disorders. However, limitations include potential parental bias and the need for further validation studies. This study explores using MRI, EEG, and fNIRS for early ASD detection in high-risk toddlers. It highlights limitations of previous techniques and emphasizes the potential of these tools for improving early diagnosis. While lacking IRB approval, the study offers valuable insights and paves the way for further research. Future directions include validating findings in larger populations and exploring combined neuroimaging approaches for more comprehensive ASD risk assessment[126].

This work explores using dMRI, EEG, fMRI, and machine learning to study brain connectivity in ASD. These tech-

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niques hold promise for improving ASD diagnosis, but limitations like parental bias and the need for more studies exist. Future research addressing these limitations can improve understanding of ASD and lead to earlier diagnosis and better interventions.

1.14. Autism Early Detection based on Electroencephalography (EEG) and Eye Tracking(ET)

EEG and eye-tracking (ET) show promise for early ASD detection in children. Studies using EEG data from toddlers as young as 3 months achieved high accuracy in predicting ASD.

Machine learning techniques applied to ET data have also yielded promising results. However, limitations include ASD heterogeneity and the impact of context on eye fixation[127].The authors in [127] combine EEG and eye-tracking data with machine learning to identify children with ASD, achieving high accuracy (85.44%). It offers a promising alternative to traditional behavioral assessments. However, limitations include the exclusion of younger children and the need for further validation studies. Future research can explore including younger participants to account for developmental differences. However, the authors in [128] explores using eye-tracking and EEG data together (Eye Tracking-EEG Correlative Analytics) to identify ASD biomarkers and understand its development. This novel approach has potential for early diagnosis and better interventions, but limitations include ASD heterogeneity and the influence of context on eye movements. The study in [129] proposes a new deep learning method (SDAE) using combined EEG and eye-tracking data to diagnose ASD in children. This approach aims to capture richer information compared to analyzing each data source separately. While initial results are promising, the small sample size limits generalizability. Future research with larger datasets could significantly improve ASD diagnosis by providing a more comprehensive data-driven approach. This work proposes a deep learning method (SDAE) for ASD diagnosis in children using combined EEG and eye-tracking data. It aims to capture richer information than analyzing each source separately. While initial results are promising, a small sample size limits generalizability. Future research with larger datasets could improve ASD diagnosis through a more comprehensive data-driven approach.

Table 1. The overall strategies, their advantages, disadvantages and the future directions that can be used for ASD.

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References	Strategy Name	Advantages	Disadvantage	Future direction
[3]- [14]	EEG Signal	contains large, extra numerous research, examine EEG to other diagnostics, discover superior algorithms, combine with different mind information, and look at strategies in real-world settings, all while final non-invasive.	Small studies, full-size facts pre-processing, negative generalizability, capacity bias, and realistic demanding situations.	Involve large, greater various research, examine EEG to different diagnostics, discover advanced algorithms, integrate with different brain data .
[15]- [25]	MRI	MRI provides detailed images and distinctive structural as well as functional information, sophisticated techniques of quantization and non-subjective rating procedure.	Interpretation of MRI is laborious and pricey, the studies include limited samples, require stronger confirmation and increase the likelihood of overfitting .	Needs larger, diverse studies, multicenter collaboration, comparisons with existing strategies, advanced algorithms, integration with MRI data.
[26] - [37]	WES	sensitive diagnostic tool for ascertaining rare and inherited mutations in relation to ASD and an excellent approach to advancing.	limited by the high interpretability of results arising from the depiction of unknown significance of varieties of asphalt, the high costs .	carry out larger and more diverse samples, sophisticated bioinformatics approaches.
[38] -[46]	Eye Tracking(ET)	Provides objective records on gaze patterns and behaviors, aiding in quantifying autism hazard and severity, mainly in young youngsters.	Short video scenarios may additionally restriction the scope of eye motion evaluation, doubtlessly proscribing insights into autism-related gaze behaviors.	Conducting longitudinal studies to seize eye movements over prolonged durations, improving knowledge of developmental trajectories in autism.
[47] - [55]	Facial Expressions	Provides objective insights into social cognition and emotional processing deficits, assisting in early identity and intervention for people with autism.	Variability in facial expression popularity and interpretation amongst people with autism can lead to inconsistent consequences, doubtlessly restricting diagnostic accuracy.	Conducting larger, various research to higher recognize character variations and growing technology-primarily based tools to enhance facial features reputation and social interplay competencies.
[56] - [65]	Behavior Coding Measures	Identifies causes of hard behaviors for targeted interventions, complements participation and quality of lifestyles for autistic kids	May require sizeable time and resources, with variability in person responses	Expand research to various populations, integrate multimodal statistics, increase technology-based gear.

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[66] - [75]	Blood Biomarkers	allows for earlier intervention, which can significantly improve outcomes for individuals with ASD.	needing more validation and unclear links to treatment options.	Need larger and more diverse studies, explore and focus on personalized therapies based on biomarker profiles
[76] - [86]	Urine Analysis	The method is not invasive as are some other methods, which is why it is more comfortable and, possibly, less traumatic for children.	shown some potential but more studies are required to establish the efficiencies.	involve bigger sample size, high quality methodology
[87] - [96]	Vision Screening	offer a promising, objective, non-invasive and potentially cost-effective way for early autism detection.	limited research, access issues and potential data bias.	should focus on bigger data, real-world testing, combining data sources.
[97] - [103]	Nervous Oscillation	Offer an goal way to study mind activity in autism, offering insights into its underlying mechanisms.	faces demanding situations in research validity, interpretation and facts consistency.	have to awareness on large studies, stepped forward evaluation, combining information resources .
[104] -[113]	Gender Types		Relying on gender in autism detection is unreliable	research on gender's position in prognosis.
[114] -[123]	The Influence of Social Media	gives huge records for autism research (language, behavior), faraway screening access, and insights from online help companies.	Social media's privateness issues, incorrect information, and constrained attain improve concerns for autism detection.	Ought to prioritize moral and contain larger, diverse datasets.
[124] -[126]	(EEG) &(MRI)	Enhancing knowledge of autism's neurobiology and potentially leading to greater correct diagnoses.	Face limitations early studies ranges, ability parental bias, and excessive value/restricted access.	Need to contain larger diverse studies
[127] -[129]	(EEG) & (ET)	offer promise for early ASD detection (as young as 3 months).	Limited studies, variable autism presentations, and excessive price/limited access	Need to contain larger diverse studies

2. *Comparative Analysis of Machine Learning Techniques for Early Autism Spectrum Disorder (ASD) Detection*

In the field of early ASD detection, various machine learning techniques can be applied. Each technique comes with its own set of advantages, disadvantages, and performance metrics. Below is a comparative analysis of these techniques are declared in Table 2 .

The passage describes various supervised machine learning algorithms including Naive Bayes, k-Nearest Neighbors, Logistic Regression, Support Vector Machines (SVM), Decision Trees, Random Forest, Extreme Gradient Boosting (XGBoost), and Artificial Neural Networks (ANN)[130].

- Naive Bayes is a simple method based on Bayes' theorem that assumes independence of features.
- k-Nearest Neighbors classifies data points based on the similarity to their neighbors.
- Logistic Regression predicts binary outcomes using a linear model.
- SVM separates data points of different classes by finding a hyperplane with the maximum margin.
- Decision Trees make decisions based on a tree-like structure with branching based on features.
- Random Forest combines multiple decision trees to improve prediction accuracy.
- XGBoost is a powerful ensemble method using decision trees with gradient boosting.
- ANNs are inspired by the structure of the brain and can learn complex relationships from data.

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Algorithm	Description	Advantages	Disadvantages
NB	Classifies data based on Bayes' theorem assuming features are independent.	Fast, easy to implement, good for small datasets.	Assumes independence of features, may not work well with high-dimensional data.
kNN	Classifies data based on the majority vote of its nearest neighbors.	Easy to implement, interpretable.	Sensitive to noise, high dimensionality can affect performance.
LR	Predicts the probability of a binary outcome using a linear model.	Interpretable, good for binary classification.	Assumes linearity between features and target variable.
SVM	Finds a hyperplane that maximizes the margin between data points of different classes.	Effective for high-dimensional data, good for small datasets.	Can be computationally expensive, not interpretable for complex models.
DT	Classifies data by following a tree-like structure based on feature values.	Easy to interpret, works well with various data types.	Can be prone to overfitting, may not be good for high-dimensional data.
RF	Combines multiple decision trees to improve prediction accuracy.	Robust to overfitting, good for complex problems.	Less interpretable than single decision trees.
XGBoost	Powerful ensemble method using decision trees with gradient boosting.	Highly accurate, efficient, handles missing data.	Complex, requires careful hyperparameter tuning.
ANN	Inspired by the structure of the brain, learns complex relationships from data.	Highly flexible, can learn complex patterns.	Can be computationally expensive, black box model(difficult to interpret)

Table 2. various machine learning techniques each with its own set of advantages, disadvantages, and performance metrics.

3. *Real-World Applications of Machine Learning Techniques in Early ASD Detection*

Traditional methods are time-consuming and require specialists. Machine learning offers promise for faster and more objective detection using various data sources, including eye fixation patterns, facial expressions, and EEG signals. This study proposes a novel multimodal approach that combines these data types using a weighted naive Bayes algorithm to improve detection accuracy[131].

This study explores machine learning for automated ASD diagnosis using a dataset of self-reported and individual characteristic data. The authors compared various algorithms (ANN, SVM, Random Forest) on datasets with and without missing values, employing feature selection to improve efficiency. Their findings suggest specific models suitable for ASD diagnosis based on missing value patterns[132].

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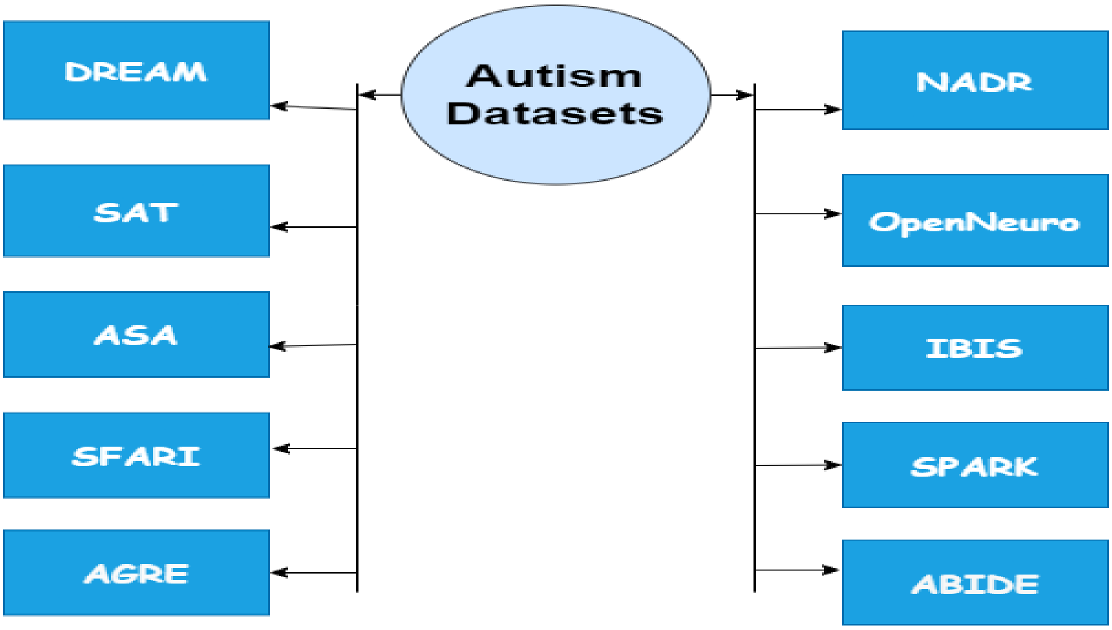
4. Autism Datasets

Figure 2. Autism Datasets



4.1. Autism Dataset Definition

Large ASD datasets like the Autism Dataset empower researchers to explore various aspects of the disorder. These datasets are used in studies on early detection, diagnosis, treatment, and identifying biomarkers using methods like facial expression analysis, brain imaging, and eye-tracking. This research improves understanding of ASD and development of effective interventions[133].

4.2. Autism Datasets Categorization

Large ASD datasets like the Autism Dataset contain phenotypic, neuroimaging, genetic, and behavioral data. Machine learning algorithms, including SVMs, random forests, and deep learning models like Xception, are applied to these datasets to classify individuals on the autism spectrum. This research using diverse data types and algorithms holds promise for improving autism diagnosis, potentially through facial recognition[134].Datasets that can be used in the process of ASD early detection are summarized in Table 3.

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Table 3. Autism early detection Dataset Examples

Dataset Name	About Dataset	Data Type	Applied Approaches
NDAR [135]	data from in many scientific disciplines	Demographic	Hall et al.[136], Novikova et al.[137], Torgerson et al.[138], Li et al.[139], and Haweel et al.[17]
OpenNeuro [140]	brain imaging data Structure	fMRI data	Markiewicz et al.[140], Traut et al.[141] and Bahathiq et al.[21]
IBIS [142]	collection of brain imaging data from infants	Genomic	Marrus et al.[142], and Girault et al.[143]
SPARK [144]	strongly encoded domain-specific	MRI scans	Arya et al.[144], Jadav et al.[145], and Bhat et al.[146],
ABIDE [147]	functional and structural brain imaging data	MRI scans	Heinsfeld et al.[147], yang et al.[148], moridian et al.[149], boughattas et al.[150], sharif et al.[151] ,Thapa et al.[134], and Adhikary et al.[152]
DREAM [153]	related to autism screening	Demographic	Billing [153]
AST [154]	used for descriptive and predictive analyses	Demographic	Romero et al.[154]
ASA [154]	composed of survey results for more than 700 people	Self-report	Romero et al.[154]
SFARI [155]	data from individuals with autism	Genetic	Grove et al.[155]
AGRE [156]	large, publicly available dataset	Genetic	Liu X et al.[156]

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The National Database for Autism Research (NDAR) is a public repository of ASD data, including clinical, genetic, and imaging data. Funded by the NIH, NDAR facilitates data sharing and analysis to improve understanding of ASD and accelerate treatment development. This resource is valuable for researchers, clinicians, and anyone interested in ASD research. Studies that utilize this dataset include those by Hall et al.[136], Novikova et al.[137], Torgerson et al.[138], Li et al.[139], and Haweel et al.[17]

OpenNeuro is a public platform for sharing and accessing brain imaging data (fMRI, sMRI, EEG, MEG). It promotes open science by allowing researchers to share and discover diverse datasets. Built on FAIR principles, OpenNeuro fosters data transparency, interactivity, and reusability for neuroimaging research. The platform's open-source code is available on GitHub. Research papers drawing on this dataset include those by Markiewicz et al.[140], Traut et al.[141] and Bahathiq et al.[21]

The Infant Brain Imaging Study (IBIS) is a large, NIH-funded study following high-risk and low-risk infants to identify early brain markers of ASD. It includes MRI, EEG, and behavioral data from birth to 3 years. This unique dataset is publicly available through NDAR and has been instrumental in understanding early signs of ASD. Research papers that have employed this dataset include those by Marrus et al.[142] and Girault et al.[143]

The Simons Foundation Powering Autism Research (SPARK) dataset is a massive collection of genetic, environmental, and behavioral data from over 50,000 individuals

The Autism Screening Data for Toddlers (AST) dataset provides data on basic characteristics of toddlers (12-36 months) for autism screening. This data can be used with tools like M-CHAT, CSBS-DP, and STAT to identify children needing further evaluation. These tools are recommended for routine autism screening in various settings. Romero et al.[154] proposed a framework that evaluated on this dataset.

The Autism Screening on Adults (ASA) dataset utilizes tools like ADI-R, ADOS-2, and AQ to assess sociality, communication, and repetitive behaviors in adults for potential ASD diagnosis. This dataset highlights the importance of routine screening across the lifespan, as autism can be diagnosed at any age. Papers uses this dataset Romero et al. [154].

The Simons Foundation Autism Research Initiative (SFARI) funds research on autism spectrum disorders (ASDs) to improve understanding, diagnosis, and treatment. They support new research projects, collaborations, and technology development, aiming to accelerate progress through information sharing. Papers uses this dataset Grove et al. Research conducted by Grove et al. [155] has employed this dataset.

with ASD and their families. This publicly available resource (through NDAR) facilitates research by offering a rich dataset for understanding ASD causes, treatments, and interventions. However, limitations include ethical considerations and the need for specialized skills to analyze the data. Studies that have drawn on this dataset include those byArya et al.[144], Jadav et al.[145], and Bhat et al.[146].

The Autism Brain Imaging Data Exchange (ABIDE) is a large public dataset of MRI scans from individuals with ASD and typically developing controls. It allows researchers to share and analyze brain imaging data to understand ASD and develop new treatments. This resource includes structural and functional MRI data along with phenotypic information. ABIDE has been instrumental in advancing ASD research. Research that has utilized this dataset includes work by Heinsfeld et al.[147], yang et al.[148], moridian et al.[149], boughattas et al.[150], sharif et al.[151] ,Thapa et al.[134], and Adhikary et al.[152].

The Autism Neurodevelopment Research and Insights Dataset (DREAM) is a subset of the ABIDE collection, offering MRI data from ASD and typically developing individuals. This publicly available resource (through NIH) facilitates research on the neural basis of ASD by allowing researchers to explore brain structure and function. DREAM has contributed to identifying potential biomarkers for the disorder. Research papers have utilized this dataset, including the study work by Billing [153]

The Autism Genetic Resource (AGR) is a public database of genetic data from individuals with ASD and their families (over 10,000). Funded by the Simons Foundation, AGR allows researchers to study the genetic basis of ASD by providing access to genetic information from simplex and multiplex families. This rich data resource is instrumental for understanding the genetics of autism spectrum disorder. Studies have utilized this dataset, including research referenced in [156].

Public datasets like ABIDE, SFARI, and AGR offer a wealth of genetic, imaging, and behavioral data on autism. These resources foster collaboration and propel research to improve understanding and support for individuals on the spectrum.

5. *Data Quality Issues in Autism Early Detection Using Machine Learning*

Large healthcare datasets offer valuable insights for patient care, but understanding their limitations is crucial. This study explored inconsistencies in diagnosing autism within a hospital dataset, highlighting potential biases and the need for more accurate data recording to improve patient outcomes[157].

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VI. CONCLUSION AND FUTURE WORK

This review highlights challenges in ASD diagnosis and treatment, emphasizing early detection. Future research should refine early detection techniques and foster collaboration for effective interventions. To advance early ASD detection through machine learning, future research should address data quality, heterogeneity, and model interpretability while ensuring ethical AI integration and clinical usability.

ML offers promise for ASD assessment using data from screening tools. While current methods achieve high accuracy, they may not reflect real-world clinical needs. This review highlights the importance of understanding both clinical assessment and ML techniques to develop more relevant and cost-effective ML-based ASD assessment systems[158].

Conflicts of Interest: The authors declare no conflict of interest.

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