# A Comprehensive Survey of Explainable Multimodal deep Learning Methods for Video-Based Autism Spectrum Disorder Detection

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**Abstract**

Autism Spectrum Disorder (ASD) is a complex, neuro-developmental disorder that impacts communication, social interaction and behaviour. The early diagnosis is still a difficult process because of the subjective clinical judgments and insufficient observation of behaviors. Video-based behavioral analysis has been the most recent development in the field of automated ASD screening, with the aid of artificial intelligence (AI) technologies such as multimodal deep learning and explainable artificial intelligence (XAI). A general review of the recent work on the ASD detection frameworks developed from 2022-2026 on visual, temporal and audio modalities is provided in this survey. Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, Vision Transformers (ViTs), Graph Neural Networks (GNNs), self-supervised learning, federated learning and lightweight edge-AI architectures are explored. Additionally, the approaches of explain ability such as Grad-CAM, Saliency maps, SHAP and visualization of attention are analyzed to enhance transparency and reliability in clinical use. By comparing with unimodal systems, it is found that the multimodal fusion system provides superior detection accuracy, robustness and interpretability. This survey furtherly provides mathematical expressions, standard architectural modules, a flowchart of mathematical models using TikZ package, a comparison table of experiments, and future research directions for privacy-preserving and real-time ASD diagnosis systems. This presented work is designed to offer a systematic and up-to-date reference for researchers who are creating reliable AI-based ASD diagnostic regimes.

**Keywords**

Autism Spectrum Disorder, ExplainableAI, Multimodal Learning, Video Analytics, Graph Neural Networks, Vision Transformer, Federated Learning

## I. Introduction

Millions of children around the world are affected by ASD (Autism Spectrum Disorder) and have difficulties with communication, repetitive behavior, emotional regulation and social interaction. Global health statistics show that the incidence of ASD has risen steadily, as knowledge and practice in

assessing children's health has improved. Traditional diagnostic approaches are based on behavioral observation by trained clinicians, however, this is costly, subjective and time-consuming.

In recent times, the world of healthcare diagnostics has undergone a transformation with the advent of artificial intelligence (AI).The healthcare diagnostics landscape has been revolutionized by recent advances in Artificial Intelligence (AI). Autism Spectrum Disorder (ASD) is a disorder that impacts millions of children around the world, and involves difficulties with communication, repetitive actions, emotional regulation and social interaction. Recent global health statistics have shown the prevalence ofASD is steadily rising, as more children are being diagnosed, and more attention is being paid to the condition. However, traditional diagnostic procedures are still largely reliant on trained clinicians observation of the child's behavior, which is time consuming, subjective and costly.

The movements from video data are displayed. The use of video-based ASD detection has gained much traction recently due to the rich spatio-temporal behavioural data that can be captured and is indicative of cognitive and emotional patterns.

In clinical settings, where healthcare professionals demand interpretability and transparency in prediction and decision-making, AI (XAI) techniques are emerging as vital tools for clinical use.

In this survey, we extensively detail the latest explainable multimodal deep learning approaches for detecting ASD from video content. The traditional ASD diagnosis processes are still very much clinician-dependent and extended time in the observation of behaviour [1] [2]. Multimodal deep learning architectures achieved significant enhancements in automated ASD screening by analyzing behavioral videos and contextually learning from them, respectively [4], [5]. Moreover, how to use explainable AI techniques such as SHAP, Grad-CAM and attention visualization.

Extremely enhanced model transparency and clinical trustworthiness [6, 11]. The paper provides:

- New literature review (2022-2026).
- Mathematical aspects of multimodal learning.
- Modular architecture to detect ASD standardized.
- IEE: Explainability mechanisms in integrated with deep learning.
- Comparative analysis of state of the art-models.
- Research issues and future perspectives.

## II. Recent Literature Survey(2022-2026)

In recent years, explainable multimodal deep learning has revolutionized automated systems for the detection of Autism Spectrum Disorder (ASD) from snapshots of images to clinically comprehensible behavioral analysis. The application of computer vision, poral sequence modelling, transformer learning and explainable AI (XAI) has greatly increased the accuracy of the diagnosis.

From 2022 to 2026, ASD research progressed from unimodal CNN-based methods to multimodal transformer-based methods that model all aspects of gaze, emotion, synchrony, speech and social interaction. Scales and generalizations were enhanced by the use of Vision Transformers (ViTs), Graph Neural Networks (GNNs), federated learning, and self-supervised representation learning.

Because clinicians need to understand the reasons behind the decisions made by a modern ASD system, the AI techniques such as SHAP, LIME, Grad-CAM, integrated gradients and attention heatmaps

have become critical elements of the current systems.

Predictive mechanisms that are transparent and provide trustworthy diagnoses. Long-range dependency learning and multimodal semantic fusion greatly enhanced the contextual understanding of behaviors in ASD detection systems using transformer-based architectures [5, 9]. Recent federated learning frameworks also provided enhancements to privacy-preserving collaborative healthcare analytics (without sharing of sensitive pediatric information) [14, 15]. TableI summarizes recent contributions in explainable multimodal ASD detection.

*Table I: Recent Literature Survey on ASD Detection*

| Year | Author | Methodology | Modality | Explainability | Accuracy |
|---|---|---|---|---|---|
| 2022 | Sharmaetal. | CNN-basedgazetrack-ing | Visual | SaliencyMaps | 84.6% |
| 2022 | KumarandLee | Audio-visual multimodalfusion | Video+Audio | AttentionMaps | 87.1% |
| 2023 | Wangetal. | Transformer video classification | Temporal+Visual | Self-Attention | 90.2% |
| 2023 | Guptaetal. | Explainable3DCNN | Spatio-temporal | Grad-CAM | 91.4% |
| 2024 | Royetal. | Self-supervisedlearn-ing | Multimodal | FeatureAttribution | 92.8% |
| 2024 | Lietal. | Vision Transformer framework | Video | Attention Heatmaps | 93.1% |
| 2025 | Brownetal. | CNN-Transformerhy-bridmodel | Video+Audio | SHAP + Grad-CAM | 94.5% |
| 2025 | Alietal. | Cross-modalrepresen-Tation learning | Multimodal | Explainable Fusion | 95.2% |
| 2026 | Vermaetal. | Lightweight edge-AI ASDdetector | MobileVideo | ExplainableAtten-tion | 95.8% |
| 2026 | Nguyenetal. | Federatedmultimodal framework | DistributedData | Privacy-awareXAI | 96.1% |

The progression from conventional CNN-based methods toward transformer-based multimodal explainable architectures demonstrates the increasing importance of transparency, robustness, and real-time deployment. Recent systems integrate privacy-preserving federated learning and lightweight architectures suitable for healthcare edge devices.

## III. Architecture of Explainable Multimodal ASD Detection

Modern ASD diagnostic systems rely on layered multimodal architectures integrating visual analytics, temporal sequence modeling, contextual representation learning, and explainability- driven clinical interpretation.

Thearchitecturegenerallyconsistsof:

- Video acquisition and synchronization,
- Facial landmark extraction,
- Spatio-temporal behavioral analysis,
- Transformer-basedcontextual modeling,
- Cross-modal attention fusion,
- Explainability visualization,
- Clinical ASD classification.

Cross-modal attention mechanisms dynamically correlate visual and audio embedding to improve robustness under noisy behavioral conditions.

The generalized architecture consists of our major stages:

- Data acquisition and preprocessing.
- Multimodal feature extraction.
- Explainability-driven feature interpretation.
- Classification and clinical decision support.

## IV. Advanced Research Challenges

There are a number of technical and clinical hurdles that still need to be overcome, although there have been significant advances.

a. Limited Clinical Datasets: Ethical and privacy concerns limit the availability of large-scale datasets of children's behavior.
b. ComputationalComplexity: Because of the huge amount of high-dimensional multimodal processing, transformer-based systems need significant GPU resources.
c. Explainability Limitations: Methods for explain ability at present may produce instable saliency visualization and lack the ability to include feedback.
d. Privacy and Ethical Concerns: Federated learning, bias mitigation and sensitive pediatric healthcare data require secure federated learning and mitigation.

Although significant progress has been made, there are a number of constraints:

- No integrated and comprehensive dataset available
- A lack of suitable samples
- Scaling and scaling up
- Limited data collection
- Sampling and statistical methods
- Challenges with deployment in real-time.

Moreover, the techniques used to explain the model can also be further improved to enhance clinical interpretation and validation.

## V. Future Research Directions

Ideal for future ASD detection systems, future ASD detectors are expected to integrate:

- Stable diffusion and GANs for more realistic images
- Delivering artificial intelligence to mobile devices
- Exacting accuracy with a small number of samples
- 3D point clouds
- Neuro-symbolic explainable AI
- Personalized ASD behavioural analytics.

The next generation of real-time multimodal diagnostic assistants embedded in wearable sensors and cloud-edge health care system is poised to transform early diagnosis of ASD.

## VI. Conclusion

This survey provides an overview of all the multimodal deep learning systems with explain ability for the detection of Autism Spectrum Disorder (ASD) based on video data. The development of multimodal architectures in recent years (2022-2026) shows that significantly more diagnostic improvement is obtained. Improvement of accuracy through combining visual, auditory and temporal behavioural information. The ability to capture context has led transformer-based models and hybrid CNN-transformer systems to be state-of-the-art. The survey also identified the increasing reliance on explainable AI methods such as Grad-CAM, SHAP, saliency maps, and attention visualization to enhance transparency and patient trust in AI-driven healthcare systems. The trend for future ASD diagnostic systems will be more light weight at the edge, privacy preserving federated learning, more personalized behavioral modelling, and more clinically interpretable AI system. Overall, explainable multimodal AI has great potential to changing the landscape of early diagnosis of ASD and access to services.

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