A Review and Comparative Study of Works that Care is Monitoring Detection and Therapy of Children with Autism Spectrum Disorder

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Abstract: - Recognizing human activity from video sequences and sensor data is one of the major challenges in human-computer interaction and computer vision. Health care is a rapidly developing field of technology and services. The latest development in this field is remote patient monitoring, which has many advantages in a rapidly evolving world. With relatively simple applications for monitoring patients within hospital rooms, technology has advanced to the point where a patient can be allowed to carry out normal daily activities at home while still being monitored using modern communication technologies and sensors. These new technologies can monitor patients based on their disease or condition. The technology varies from sensors attached to the body to peripheral sensors connected to the environment, and innovations show contactless monitoring that only requires the patient to be within a few meters of the sensor. Nowadays, the Internet of Things, wearable devices, mobile technologies, and improved communication and computing capabilities have given rise to innovative mobile health solutions, and several research efforts have recently been made in the field of autism spectrum disorders (ASD). This technology may be particularly useful for some rapidly changing emotional states, especially people with ASD. Children with ASD have some disturbing activities, and usually cannot speak fluently. Instead, they use signs and words to establish rapport, so understanding their needs is one of the most challenging tasks for healthcare providers, but monitoring the disease can make it much easier. We study in this work more than 50 collected articles that have made a significant contribution to the field were selected. Indeed, the current paper reviews the literature to identify current trends, expectations, and potential gaps related to the latest portable, smart, and wearable technologies in the field of ASD. This study also provides a review of recent developments in health care and monitoring of people with autism.

Key-Words: - ASD, HAR, HealthCare, Monitoring, AI, IoT, Kinect, Sensors, Robots.

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1 Introduction

Since the past years, we have witnessed great progress and great effort to build innovative computer vision applications that cover different fields, despite the very wide spectrum of these applications, few solutions have been designed to help people with autism. Computer vision technologies for supervising people with ASD are still in their infancy. There has been limited research addressing this topic, and we will outline some of the current work aimed at providing automatic recognition of basic emotions expressed by autistic people during a meltdown crisis Although there are multiple facilities for overcoming autism in daily life, it is impossible to meet the special needs, especially those related to the security of autistic children during an autistic crisis. Highly functional autistic children often go through severe autistic crises and breakdown can occur due to sensory overload. It can happen when children are alone and lose control of their behavior by unintentionally hurting themselves or others. An autistic child may display the variable symptoms of a breakdown in his abnormal behavior according to different scenarios, [1]. COVID-19 has played a huge role and has been an important reason for the development of monitoring technology in the healthcare field, [2].

The proliferation of Information and Communication Technologies (ICTs) and the widespread adoption of consumer electronic devices such as wristbands and smartwatches, provides an opportunity to use these technologies to simultaneously monitor the health and well-being of a patient there is a lot of data physiological signals and parameters used in physiological and emotional evaluation provided by these devices, such as (heart rate, respiratory rate, electrical activity of the skin, skin, and body temperature, blood pressure, blood oxygen saturation, electromyography, electroencephalogram), all these sensors mentioned above, it can contribute significantly to the development of the healthcare field, [3].

Autism or "autism spectrum disorder (ASD)" is characterized by abnormal communication and social interaction, with restricted and repetitive behaviors. There is no doubt that people with autism are a growing part of our society. In addition, the most recent studies conducted by the Centers for Disease Control and Prevention (CDC) in 2018 estimated that the prevalence of autism could be between 90 and 120 individuals out of 10,000, which is about 1% of the population, [4].

Autism is a neurological disorder that causes slow brain development. Individuals with autism find it difficult to relate to others, learn new things, express their feelings, adjust to a new situation, and so on and They become isolated from society because they are unable to interact properly with others. They cannot understand other people's behavior and intentions, they have difficulty thinking outside of their routine The current world is moving towards an intelligent society based on the Internet of Things, where AI-enabled devices will be everywhere. People will get help through it, which will reduce human intervention across a variety of sectors. It would be beneficial to design these devices for autistic individuals as well because they can significantly reduce the requirements for human assistance. These devices can help them become self-reliant and they can live on their own with the help of these devices. This will help a lot in integrating them into the main part of society, [5].

Individuals with autism have difficulties from early childhood into the rest of their lives. They need special education, special sessions, and a special way of interacting and understanding, [6].

A shortage of hospital resources such as doctors, beds, and nurses is imminent around the world and the cost of treating chronic diseases continues to increase. In such emergencies, the smart monitoring app is particularly useful, as it automatically triggers an alert in the event of a crisis based on an analysis of abnormal facial expressions of children with autism or by analyzing the data of other sensors associated with the patient, [7].

Modern technologies based on artificial intelligence, machine learning, and the Internet of Things have proven their ability to assist in real-life applications. It is also used for autistic individuals to make their lives easier. The field of Human Activity Recognition (HAR) has become one of the most popular research topics due to the availability of sensors and accelerometers, lower cost, lower power consumption, real-time data streaming, and advances in computer vision, machine learning, Artificial Intelligence (AI), and the Internet of Things. The procedure for identifying human activity consists of four basic stages. These stages are data collection, feature extraction, classification, and recognition activities, [8], [9], [10], [11], [12]. Most researchers used different ML and DL algorithms such as SVM, LR, NB, ANN, KNN, etc., and DL algorithms such as CNN, Recurrent Neural Network (RNN), etc. to monitor autism. Apart from these algorithms, they used different image-processing methods for feature extraction and adopted different rule-based methods such as fuzzy logic to classify ASD. Systems based on Internet of Things (IoT) devices offer several useful features that facilitate remote monitoring for people with autism. Thus, healthcare applications that make use of IoT devices have started to gain traction in recent years, [13], [14].

Moreover, sensors are now being built into devices to analyze activity, movement, and the state of the environment. Various sensors and devices have been widely used in research work on autism, where the data collected from different sensors are sent to the smart grid to communicate with the system. A smart grid is a network through which connectivity is provided to the various entities involved in the healthcare system, [15], [16]. Furthermore, the design of technologies and their integration into the concept of smart cities is inevitable. There should be many technologies in hospitals, restaurants, transportation, offices, homes, and even in educational institutions through which an autistic person can get all the facilities that a normal human gets. They all need to be tracked through all the smart devices and cameras and monitored in a regular way to help them with any kind of problem, [17]. Indeed, image processing is a growing technology and can be used in various fields such as medical imaging, computer vision, computer graphics, etc. Image processing is a method that takes an image as an input, performs some operations on it, and gives the image as an output. Image processing operations are divided into image optimization, restoration, segmentation, extraction, and recognition. Image processing technologies can play an important role in helping healthcare providers monitor patients with autism, [18], where the development of wearable and mobile technologies that target the aforementioned areas can improve the lives of both children with autism and the lives of parents by providing a way for children to become self-reliant. Nowadays, smartwatches and other wearable devices have enough processing power and memory to help children with autism. Can help collect health data from integrated sensors that can help monitor. In general, wearable devices and mobile technology can help children with autism in several areas, especially in the field of health care, [19].

Surveillance of autism spectrum disorder has become a popular and active research area for researchers over the past two decades. However, it remains a complicated task due to some unsolvable issues such as sensor motion, sensor placement, background clustering, and the inherent variance in how autistic people perform different activities.

Automatic ASD activity recognition has been one of the challenging issues in computer vision in recent years. It is of great importance in various applications of artificial intelligence like video surveillance, computer games, and robotic and human-computer interactions. This review aims to stress the need for automating, processing, and classification to recognize Autistic children's activities from a dataset. There are challenges for the potential clinical adoption of those wearable technologies. First, most existing devices on the market are designed for the general population with little attention to people with ASD. Second, the use of these devices requires training for users and their caregivers. Third, even when devices are designed for people with ASD, the cost of purchasing and gaining continuous service for some devices can be expensive for parents and caregivers. There are some major issues with the modern healthcare system like the precision of the system, security, and protection of valuable data, and poor data analysis techniques that must be solved to promote healthcare service. One problem highlighted in this work is that medical institutions lack a unified standard among different organizations and regions, and there is a need for improvement to ensure data integrity. As extensive data must be gathered, it will likely make the system rather complicated, which will lead to difficulties in communication and data management.

The rest of the paper is structured as Section 2 contains the related work of recent research papers in the field. Section 3 briefly describes the various methods and techniques used in ASD monitoring with analysis and summary for each research study based on the presented taxonomy. Section 4 presents an analytical discussion based on the reviewed research studies. Section 5 contains our findings with some concluding remarks and future scope.

2 Related Works

Interacting with autistic children is one of the most challenging issues that their families and caregivers deal with. In recent years, systems based on the monitoring and treatment of children with autism have received much attention. Many articles have been committed to treating ASD or diagnosing diseases, but few relevant papers have been submitted to investigate ASD monitoring regimens in the same way. Several reviews of relevant literature have been published, examining technologies that can enable physiological and emotional monitoring remotely, using different sensor modalities.

Computer vision technologies for supervising people with ASD are still in their infancy. There has been limited research addressing this topic. Below, we will outline some of the current work aimed at providing automatic recognition of the basic emotions and physiological signals that appear in autistic people during a crisis breakdown (abnormal emotions). These works can be classified As shown in the Figure 1.

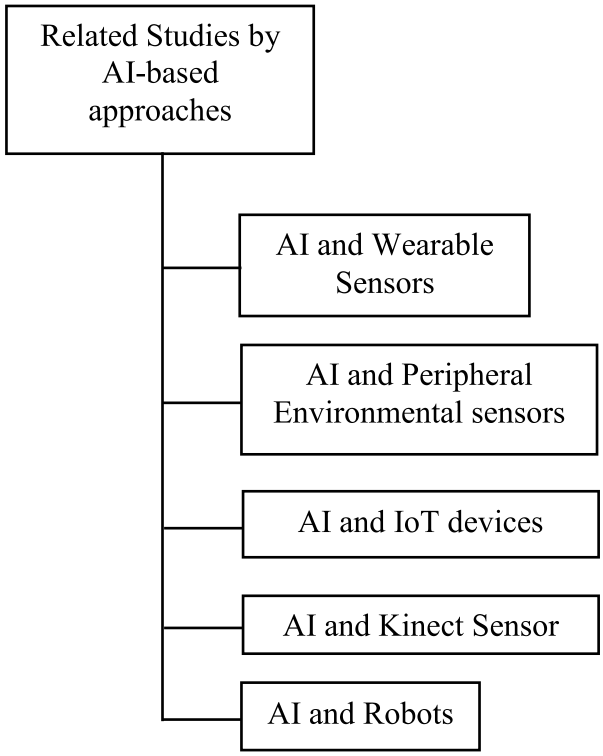

Fig. 1: Related studies classification for autistic people monitoring

2.1 Related Studies by AI-based Approaches

By reference, [20], in this study, an activity prediction methodology based on 3D CNN and LSTM is proposed to identify somatic irregularities. A 3D CNN model extracts spatiotemporal features from video templates to predict position with subject position. The LSTM model calculates the temporal relationship in feature maps to analyze the measure of irregularity. Moreover, to deal with such irregularities, a time-sensitive alert-based decision-making process was proposed in the present work to generate early warnings for the clinician and caretaker.

In the study [21], the researchers focused on evaluating the accuracy of the Eye-Tracker algorithm, a phone-based eye-tracking technology, in distinguishing between gaze towards the eyes and mouth of a face displayed on a smartphone screen. This technology can be used to monitor gaze aversion behaviors in individuals with ASD over an extended period through a mobile-monitoring tool. The researchers employed a convolutional neural network trained on a large eye-tracking dataset, recorded under home-use conditions, to estimate the gaze location. As a result, patients can regularly perform a series of tests on their smartphones that measure their gaze behaviors, providing valuable insights into the progression of their condition over time. It is also under the same context as above.

We can put the proposal in the study [22], in the same context, that suggested a system autism screening system that replaces the conventional scoring functions in classic screening methods with deep learning algorithms. The system is composed of a mobile application that provides the user interface for capturing questionnaire data. an intelligent ASD detection web service that interfaces with a CNN trained with historical ASD cases. The database enables CNN to learn new knowledge from future users of the system. Autism AI System is composed of a mobile app, an Intelligent Autistic Traits Detection web service that enables communications between the Autism AI app and the CNN, a database to store the subject's responses and test results, and the CNN screening algorithm that detects autistic traits. The Autism AI app is required to communicate with the web service that interfaces and implements CNN. The app captures and verifies relevant user data (behavioral traits and demographic features) and feeds them to CNN via the web service. The Autism AI app also generates a report that the user can provide to health professionals.

The study [23], also under the same context identifies the children with ASD in raw video data using a deep learning technique in three stages. Firstly, to investigate different gaze patterns between ASD children and typically developing (TD) children, we track the eye movement in each video by the tracking-learning-detection method. Secondly, they divide these tracking trajectories into two components: (I) the length; and (II) the angle. Afterward, they calculate an accumulative histogram for each component. Finally, they adopt a three-layer Long Short-Term Memory (LSTM) network for classification. In this work, they propose a framework to help classify ASD children in raw video data This framework has consisted of four stages: (i) manual labeling; (ii) eye tracking; (iii) histogram computation for the length and the angle, respectively; and (iv) construction of long short-term memory (LSTM) network for classification. Firstly, they manually choose the eye area and apply Tracking-Learning-Detection (TLD) to obtain trajectory features, which can be divided into the length feature and the angle feature. In this system, after the feature extraction stage, the features of the input data are extracted in the form of two graphs that represent time series data. The system sends the chart to the graphical analysis stage. At this stage, the short-term memory algorithm classifies the data and sends it to the final stage, which is the stage of showing the results.

As for the proposed self-tracking system in the study [24]. This work is based on the idea of the ability of adolescents with autism to self-tracking using customizable tools to suit their needs in adulthood, and whether this tool will be successful in this challenge or not. In this work, they investigated how adolescents with ASD kept track of their everyday lives using a custom self-tracking platform, called Omni-Track. The Omni-Track method enables each user to create a personalized tracker by customizing tracking items to support practical or emotional needs. Furthermore, Omni-Track benefits both users, by allowing them to collect data on their daily activities, and researchers, by providing an experimental toolkit to manage experiments and analyze the collected data. They installed Omni-Track on the participants' smartphones to observe how they used it over a period, to elicit feedback on how the use of Omni-Track may or may not have addressed their needs and concerns, and to critique the technology by describing their experiences.

The proposed methodology in the study [25], aims to introduce children to various emotions, improve their emotional state, recognize emotional manifestations in others, respond to negative emotions, reduce anxiety, and overcome fears. They suggest a system with five main processes, which are downloading emotional videos, setting options for learning neural networks, analyzing images using a neural network, getting emotional statistics, and providing guidance on learning through AI. The system also uses two databases - Emotions and Data from students with autism. The fifth process, guiding learning through AI, is further broken down into four subprocesses, which include obtaining the result of recognizing the emotions of a student with autism, analyzing key moments of emotional reactions, preparing a personal teaching methodology based on a recognized emotional state, and making recommendations to improve the response of students with autism. It is also under the same previous context.

The study [26], proposed a system for detecting autism spectrum disorder (ASD) using various machine-learning methods. They experimented with feature selection methods, analyzed the impact of different features, and tested different machine-learning algorithms. They used the Autism Screening Adult Dataset, which contains missing data, and handled it by either deleting rows or replacing missing values. They used various classifiers such as Naive Bayes, Logistic Regression, K-Star, SGD, SMO, AdaBoost, OneR, Random Forest, MLP, and CNN with their default hyperparameters, except for MLP where they used 1 hidden layer with 65 hidden units and SGD solver. For CNN, they used a basic 1D convolutional layer, followed by a pooling layer, dense layer, and output layer. It is also under the same context as the one that precedes it.

2.1.1 AI-based Approaches and Wearable Sensors

In the reference [27], are proposing a system consisting of a Smart Wrist Band (SWB), an interactive monitor, and a camera device attached to the monitor for monitoring ASD patients. These devices are connected to a mobile application to continuously monitor and keep them in a learning environment all day long without caregivers. The SWB consists of an accelerometer, gyroscope, magnetometer, GPS tracker, heart rate sensor, pedometer, and temperature sensor. The output device be a sound box and a computer screen, which will contain a camera to take images of the patient for emotion analysis every 5 min. AI models will analyze the health condition of the autistic individual and operate through some visuals and sounds.

Wearable sensors were used in the study [28], proposed a system consisting of wearable devices that includes sensors for measuring heart rate, skin resistance, temperature, and movement. A dedicated software application allows for generating reports to evaluate therapeutic effects. The device is comprised of a wristwatch-like protective case integrated into an elastic band, maintaining the contact of the sensors with the skin. The electronic module contains an inductive (contactless) battery charging system, with the receiver coil located on the outer face of the module.

The same method was used in the study [29], The same method was used in the study with some other additions that suggested a wearable emotional-based e-Healthcare controller using electrodermal activity and speech recognizer sensors to obtain physiological data from autistic children. The system architecture is divided into two modules, the first effective controller and e-Healthcare modules. The second effective module comprises an emotional controller, an emotional mobile application, a dedicated MATLAB server, and a recommender sub-module. The emotional controller includes the following components, an Electro-dermal activity (EDA) sensor, a Speech recognizer sensor, a Liquid Crystal Display (LCD) screen, Bluetooth, and a Buzzer. The EDA sensor is used to measure alterations in the skin’s ability to conduct electricity in the sympathetic autonomic nervous system and the Speech recognition sensor is used to capture some sets of commands from the patients. The recommender sub-module gathers inputs from autistic patients, which are further analyzed and classified using a fuzzy inference system (FIS) to map out emotion into seven emotional outputs.

The proposal mentioned in the study [30], is quite like the previous studies, this study aimed to evaluate HR during different interactive activities as a possible indicator of stress response in children affected by ASD as compared to children with language disorder (LD). The system also explores whether this association varied according to gender, age, or cognitive ability. The system consists of a small wearable thoracic belt, suitable for children. It has been merged with three electrocardiographs and a piezoelectric sensor to monitor cardiorespiratory activity in children with ASD and language disorder (LD). The monitoring system includes a microcontroller with a wireless interface able to transmit the acquired parameters to a personal computer for post-processing analysis. The wearable sensor device integrated a three-lead electrocardiograph (ECG) sensor for cardiac activity monitoring. The system is characterized by an ad-hoc prototype circuit board in which the signals from the three-way ECG are carried out.

In this context too it was mentioned in the study [31], proposed a deep normative modeling as a probabilistic modern detection method, in which they model the distribution of normal human movements recorded by wearable sensors and try to detect abnormal movements in patients with ASD in a novelty detection framework. In this proposed deep normative model, a movement disorder behavior is treated as an extreme of the normal range or, equivalently, as a deviation from the normal movements. In the context of abnormal movement detection, they are using wearable sensors, modern detection is defined as detecting atypical movements in the test phase while only normal movements are available in the training phase. In this study, they consider a probabilistic modern detection approach consisting of three steps: the first step is learning the distribution of normal movements using a probabilistic to denoising autoencoder. The second step is quantifying the deviation of each test sample from the distribution of normal movements, the so-called Normative Probability Map (NPM) in the normative modeling framework. The third step consists of computing the degree of novelty of each test sample by fitting a generalized extreme value distribution on summary statistics of its Normative Probability Map (NPM).

As for what was referred to in the study [32], under the same context, they proposed a system for assisting in intervention strategies for Autism Spectrum autism spectrum disorder fuzzy logic-based expert system. The system collects data from four sensors (GPS, heartbeat, accelerometer, and sound) via smartwatches, and consists of three units: sensing, data processing, and application. The data processing unit uses the expert system and external database to process the collected data, determine a solution for each session, and generate decisions with related information and commands. These decisions are sent to the application unit as alarms or notifications and stored in the external database to improve the expert system's knowledge base. Concerning parents and caregivers, an application has been proposed that works on smart devices and performs the function of monitoring and management, as well as receiving notifications about any activity related to the sick child, in addition to his actual location, daily measurements, and other data.

In the same context, the study [33], the system proposed in this study contains nodes. These nodes represent multiple sensors, some of which specialize in sensing the skin and others for monitoring reactions related to the feelings experienced by people with autism disorder. These nodes or sensors read the data and transmit it to the server using the MQTT protocol. The data is collected by training the system on the dataset used. The data collected from various sensors is sent to the server to be later displayed on smartphones and personal computers.

Similar work proposed in the study [34], this study proposes a system based on EEG sensor data for people with autism. Then this data is classified and its features are extracted using a binary pattern to create spectral images of the brain. The extracted images are applied to three models (MobileNetV2, ShuffleNet, and SqueezeNet). These models are trained. Previously, we extracted image features in a deep, uncomplicated way. A two-layered ReliefF algorithm is used for feature ranking and feature selection.

The proposed work in the study [35], too It is like the previous work, which proposed a health monitoring system consisting of four parts: a wearable module for collecting physiological data, an intelligent medicine box module for managing medications, a smartphone app for monitoring data and receiving alerts, and a remote monitoring server module for medical professionals to access data. The wearable module includes sensors for pulse, blood pressure, heart rate, and temperature. The smartphone app has modules for user information management, data processing, medication management, and alerting abnormal data. The system uses several algorithms for monitoring, including the effective independence method (EFI), QR Decomposition Method, modal kinetic energy method (MKE), modal strain energy method (MSE), and Guyan Model Reduction Method. These algorithms are used for configuring sensors on the degrees of freedom of the model, ensuring effective monitoring of the patient's physiological condition.

2.1.2 AI-based Approaches and Peripheral Environmental Sensors

In this context, it was mentioned in the study [36] to monitor and detect autistic people and any incidents that may occur as well as to inform the user, caregiver, or anybody else concerned about the incident in the house. It consists of three basic modules—the mobile module, the web service module, and the sensor module. The mobile module communicates with the web service module through Wi-Fi or cellular network. An Android application configures the user’s preferences such as the way he/she would like to be informed about an incident. These alert options can involve either playing audio, starting a vibration or displaying an animated image. The web service module is connected to a central computer at the user’s house. This module needs an Internet connection to receive requests from the user’s mobile device and a wireless connection via Wi-Fi to receive the data collected by the sensors. At this stage, there is an abstraction and data processing module, where these data are stored, analyzed, and inferred. The sensor module controls and manages the sensors.

Works like what was mentioned in the study [37], proposed a framework that includes several devices, including Tri-axial accelerometers to collect movement data. accelerometers selected as discrete and transferable devices with flexible placement. Accelerometers were applied in front of the child at the wrists, waist, and/or ankles, or within pant pockets. A maximum of six accelerometers were placed on each child. Video recordings were also obtained for each child, using three cameras. Two side cameras and an overhead camera. These recordings provide labeling for the accelerometer data. These devices are used for Self-injurious behavior detection. The purpose of using it is to determine if a model could be created to detect a behavior with imminent harm versus any other behavior, including Stereotypical motor movement.

In the study [38], have designed a system that monitors the temperature, humidity, gas levels, PPM levels, and flame in a house. The system uses various sensors including MQ-135, MQ-3, and DHT11 that are connected to an Arduino Uno board, which acts as the processor. If any of these parameters exceed a threshold level, an alert is triggered, and appropriate actions can be taken. The data generated by the sensors is stored in the Thingspeak cloud and if any abnormal condition is detected, the user is notified through the Pushbullet application. The system also includes a buzzer as an actuator to alert the user of danger. It also falls under the same context as the one that precedes it.

2.1.3 AI-Based Approaches and IOT Devices.

The above method was mentioned in the study [39], and proposed a hardware-software system for the early detection of reactive conditions and other deviations in the behavior of children. The system uses deep learning of artificial neural networks to recognize the movements and facial expressions of the child. It also includes virtual and augmented reality to create educational modules for social adaptation, telemedicine technology for remote monitoring by doctors, and IoT technology for managing mobile health devices. The system includes a set of mobile medical devices and a program complex for device control, which monitors the mental and physiological functions of the body. The devices include a portable EEG, a wearable wrist tracker, an infrared ear thermometer, impedance meter weighing scales, indoor environmental monitoring sensors, monitoring of weather conditions, and a video camera with software for remote recognition of emotions. The system also includes a hardware-software system for psychological relaxation using the impact of virtual reality. The system uses methods of intelligent data processing to support medical decision-making through the analysis of data from mobile medical devices and the automated processing of questionnaires.

The proposed work in the study [40], is like the previous work, which proposed a business process model and notation (BPMN) extension to enable the Internet of Things IoT-aware business process (BP)modeling. Second, they present IoT-fog-cloud based architecture, which (i) supports the distributed inter and intralayer communication as well as the real-time stream processing, (ii) enables the multiapplication execution within a multitenancy architecture using the single sign-on technique within a multitenancy environment, (iii) relies on the orchestration and federation management services for deploying BP into the appropriate fog and/or cloud resources. Third, they model, by using the proposed BPMN 2.0 extension, smart autistic child, and coronavirus disease 2019 monitoring systems.

2.1.4 AI-based Approaches and Kinect Sensor

The methodology, [41], involves using a Kinect sensor to monitor the interaction between two people using a Bidirectional Long Short-Term Memory Neural Network (BLSTM-NN). The 3D skeleton of each user is detected and tracked using the Kinect, and the data is modeled using BLSTM-NN. This system uses the Xbox 360 sensor to collect data. The collected data is a 3D tracking of the skeleton of a person suffering from autism. The system was applied to two people. The system works to extract features of each person's skeletal movement using the classification algorithm BLSTM-NN which is pre-trained to recognize skeletal movement and extract its kinematic features.

The methodology in [42], proposed system is based on extracting features of temporal and spatial activities as well as fine facial expressions of children with autism during a collapse crisis and in the natural state of the same person. The previously recorded data is compared using the Kinect camera in both cases (natural, collapse crisis). Temporal and spatial emotion features are extracted using deep science algorithms, recurrent neural networks, and long-short-term memory, to classify them and determine the relevance points between them for both cases. The researchers aimed to prevent overfitting and enhance the classification accuracy while eliminating repeated and insignificant features. It is also under the same context as above.

2.1.5 AI-based Approaches and Robots

This method was used in the study [43], to develop a robot-assisted therapy (RAT) system that enables a robot to assess a child's behavior by inferring their psychological disposition and mapping it to appropriate actions under the supervision of a therapist. The system generates task-based social behaviors to achieve therapeutic goals and allows robot control to be shared with human therapists to ensure safe and ethical behaviors. The system applies to various therapeutic scenarios and platforms and analyzes recorded data to provide information to different parties. An advanced sensory system translates multisensory data, such as a child's movement, gaze, vocal prosody, emotional expression, and typical ASD behaviors, into meaningful information using different techniques applied to raw images captured by RGB cameras and Microsoft's Kinect sensors.

Within a context very similar to the above was suggested in the study [44], is a robot-mediated therapy and assessment system for children with autism spectrum disorder (ASD) of mild to moderate severity and minimal verbal capabilities. The system uses an NAO humanoid robot with an additional mobile display to present emotional cues and solicit appropriate emotional responses. The mobile phone displays emotions using a custom-designed mobile application called "Emotions Selector," which accepts control messages to switch between emotion photos as single-character data from the computer via a TCP socket connection over Wi-Fi. The attention score is calculated using the mobile phone's camera, which is configured as an IP camera using an IP camera mobile application utilized for face detection to produce and accumulate an attention score. The Haar classifiers are used to detect the faces of patients from the image frames received from the mobile camera. The assessment system increases the attention score if the patient is facing the front of the robot body, where the mobile phone is attached, and decreases the attention score if the patient's face is not detected. The operator can change the preset increment and decrement values for individual patients, and this score value is updated in each iteration of the algorithm continuously.

The focus of this review is to summarize the various existing new techniques to monitor the behavior and physiological parameters of children with autism in the case of autism spectrum disorder (ASD) are shown in Table 1 (Appendix) and Table 2 (Appendix).

3 Discussions and Analysis

We classified the discussions of previous studies based on the techniques used in monitoring, treating, or detecting autistic patients. Therefore, we put each discussion group under a specific title as follows:

3.1 Wearable Devices for Monitoring Physiological Signs of Individuals with ASD

The proposed system of [27], has the potential to improve care and reduce caregiver burden, limitations include privacy concerns, accuracy of AI models, cost, user acceptance, technical issues, and lack of human interaction. Also, in [28], the proposed system in this work relies on wearing a battery-operated device that includes a sensor that measures the vital parameters of a person suffering from autism. Among the features of this device is that it is portable, comfortable to wear, and does not require surgical tools to install it on the patient's body. The most prominent potential concerns with the system are (the accuracy of the data recorded by the sensor, the life of the battery used, and privacy and security issues related to patient data), so we believe it is necessary to consider these factors again and re-evaluate them. In the study [39], the methodology proposed has many advantages, the most important of which are (interactive monitoring, and remote monitoring by specialists). There are some potential concerns that we believe affect the system's operation: (privacy and security issues related to patient data, cost, virtual reality). The methodology presented in [30], its most important features are the use of non-surgical tools and wireless data transfer. These features are considered effective and convenient for researchers and medical care professionals. Despite this, we believe that the proposed system has some drawbacks, the most important of which are (that the system works on a specific age of patients, the size of the samples used to train the system, the limited temporal and spatial scope, and the difficulty of learning for children with autism spectrum disorder). In a study [32], the proposed system relies on wearable devices that include a GPS sensor. The sensor is connected to a health care system that can create alerts and send notifications to parents or health care providers. The things we mentioned are an advantage of the system because they help facilitate health care. But from our point of view, we see that the system may have some disadvantages, for example, wearable devices are sometimes annoying, especially during movement, the accuracy of the data read by the sensor, privacy, and security issues, and perhaps the cost, which depends on the type of device used. The methodology proposed in the study [34], based on relies on extracting features of data read by an EEG sensor. This sensor is distinguished by the accuracy of reading data. The system uses algorithms that are not computationally complex and accurate in determining the features of the extracted data. However, we still believe that the system has some drawbacks, such as the size of the samples allocated to train the system, and thus a lack of diversity of data, clinical applicability, and generalizability of the system. The methodology used in the study [35], includes smart monitoring units, wearable sensors, an intelligent management system for used medications, real-time remote monitoring, and advanced algorithms. Therefore, this system features the possibility of comprehensive smart monitoring in healthcare institutions. Some of the system's disadvantages are issues of data privacy security and cost.

3.2 Methodologies for Predicting and Detecting Somatic Irregularities in Physical Activities of Autistic Children

In a study [20], the methodology proposed relies on two basic algorithms (3D CNN, LSTM) to analyze the physical activities performed by children with autism spectrum disorder. The advantages of the methodology are to keep the person safe, monitor him, and provide him with assistance. We believe that the system's concerns are limited, namely ethics, limited data, perhaps high cost, and limited scope of application. The methodology proposed in the study [37], uses a 3D accelerometer sensor to detect disordered behavior by analyzing video recordings of people with autism. The features of the system are the accuracy of the recorded data and the flexibility of the data recording process. However, the system has potential limitations: cost, ethical concerns, generalizability, technical challenges, and difficulty convincing test participants. For our part, we believe that examining the limitations mentioned in this study is important for future researchers. The proposed methodology in [41], relies entirely on the Xbox 360 sensors, and this system may be characterized by high efficiency in the process of collecting and analyzing data. One of the most important limitations that the proposed system may suffer from is the amount of data entered and the accuracy of determining the activities practiced by the infected person. The methodology proposed by the proposed system in [31], is based on wearable sensors and has many advantages, the most important of which is the use of a simple statistical system with little complexity, effective detection of abnormal behavior, and the generality of the system. However, the system has some disadvantages, including limited application, lack of training data, and reliance on auto-encoder methodology.

3.3 Monitoring Behavior, Feelings, and Data Management of Children with Autism Spectrum Disorder

In the [29], the proposed system relies on sensors that can be worn by the patient and are used to recognize the electrical activity of the skin, and other sensors to recognize speech. This process is managed by an electronic healthcare controller. The system has many advantages (wearable devices, uses fuzzy inference system, multi-module) but the reliability of electrodermal activity, implementation cost, and complexity of the system architecture are potential limitations that should be taken into consideration in the future. However, the system remains an effective tool for healthcare providers for children with autism spectrum disorder. The proposed methodology in [36], includes mobile phone units, sensors, and web services. The system provides many advantages, including data collection and access, real-time monitoring, and customizable alerts and notifications. Lack of experience among system users and some issues related to patient privacy are the most important potential limitations of this system. But in general, the system is effective in helping individuals with autism. Either in [21], eye tracking is the main tool used in this work. The eye-tracking tool works through the smartphone application platform. The tool works on a wide range of patients. The difference in smartphone application systems and platforms and their compatibility with the tool may pose a challenge or limitation to this system. In [33], the skin sensors are the sensors this system relies on. The function of these sensors is to measure the electricity of the skin and the resulting emotional changes. What distinguishes this methodology is the operation of the sensors in the Internet of Things system, which gives ease and flexibility in the process of managing the system remotely. The system may suffer from some limitations, the most important of which are location, size of samples used to train the system, privacy, and accuracy of emotion recognition. the proposed methodology in [23], that works through deep learning technology. It uses video data as input to the system. The system's function is to analyze video data to identify children with autism. The proposed system is distinguished by several things, the most important of which are accuracy in the process of tracking patient behavior, efficiency in the process of extracting time series features from video frames, and the process of classifying the output data. The most prominent limitation of the proposed methodology is the size of the data used in the system training process. The proposed methodology in [24], it based on a tool called Omni-Track. The function of this tool is to help adolescents with autism self-manage their behavior until adulthood. This system is characterized by self-management and customizability. The system has potential limitations including potentially biased self-reporting, unsupervised healthcare providers, and the size of the samples used to train the system. Therefore, these restrictions must be taken into consideration. However, in general, the methodology is considered a useful self-management tool for adolescents with autism spectrum disorder. The system proposed in [25], relies on artificial intelligence to help children with autism spectrum disorder recognize their feelings and help them manage their emotions better. This is an advantage of the system in addition to the ability to customize and improve the accuracy of emotions. A potential concern for the system is that children become completely dependent on the system to internalize their emotions rather than learning to manage their emotions independently. Therefore, it is important to weigh the advantages and disadvantages of the system to promote emotional development in children. The methodology presented in [42], relies on deep learning algorithms in addition to the Kinect camera and the Face Basics API to accurately detect subtle facial expressions in children with autism during a meltdown crisis. This methodology aims to distinguish between the complex emotions of children with autism during a meltdown crisis. Possible disadvantages of the system: The complexity and size of the system used may be a problem for some developers, as the size of the samples used, and the type of data used, which is limited to collapse crisis data only. Despite this, the methodology is a good tool and a quick solution for recognizing facial gestures in real time for children with autism.

3.4 Technological Approaches for Assessing and Treating Autism Spectrum Disorder (ASD) by using Robots

The methodology described in [43] relies on a robot supervised by healthcare professionals. It helps children overcome the period of autism spectrum disorder. The advantages of the system are the ability to work on multiple treatment scenarios. The most prominent concerns with the system are cost, ethical considerations, technical limitations, and social and cultural factors. Therefore, we believe that the system and tools used still need more research to understand the effectiveness of using robots in treating autism spectrum disorders. The proposed system in [44], the robot is also used to treat and evaluate cases of autism spectrum disorder in children. The system provides the advantage of accurate representation of the patient's attention level, as well as system customizability, ease of use, and scalability. The system allows the patient to interact with the robot, which reduces the emotional and cognitive burden that the autistic person suffers from. The proposed system may suffer from some limitations, the most important of which are remote or indirect monitoring by healthcare providers, and the amount of data used to train the system. In the [22], the proposed a methodology based on deep learning algorithms. The system is distinguished by many things, the most important of which is the accuracy of extracting data features. The most important limitation of the system is the size of the system training data.

3.5 Internet of Things Technology to Monitor the Environment Surrounding Children with Autism

In this part of our study, we found that what the presented in [40], corresponds to this title, The proposed system is based on several techniques. These technologies are compatible with the Internet of Things. The complex structure of the proposed system is perhaps its most prominent challenges and problems. Also, the same context in [38], the temperature, gas, and humidity sensors, in other words, the surrounding environment sensors, are what the proposed system is based on. In abnormal circumstances, the system sends notifications to healthcare providers. The system is effective and easy to use, and this is classified under the features section. Except for the technical problems that the system sensors may encounter.

3.6 Machine Learning to Identify Autism Spectrum Disorder

In the [26], they can be listed under the same heading. The proposed system in this work relies on several machine learning classifiers. The system chooses the appropriate classifier for the problem. Determining the behavior of system algorithms in changing conditions, and how to extract data features, is the main goal of this system. The researchers used more than one technique to collect data, and two methods to address missing data, and this increased the accuracy and size of the data. The incorporation of Neural Network classification techniques further enhances the methodology's suitability for the problem. However, limitations such as dataset limitations, feature selection limitations, classification technique limitations, overfitting, and generalizability should be considered. Nonetheless, the proposed methodology remains an effective way of detecting ASD with a high level of accuracy.

4 Conclusion

Autistic children are part of our society, but sometimes they are considered differently, and sometimes they are neglected. They go through a lot of hardship in their life and find it difficult to cope with the normal environment. Therefore, they always remain dependent on others. IoT, ML, and AI techniques can help them a lot to overcome these situations. IoT and AI-enabled devices can assist them by evaluating their condition and can keep them within a controlled environment without the need for any caregiver. A short overview of many works was provided, and the previous articles were compared based on their performances. Some research scopes and challenges in this field were mentioned and some recommendations for further research works.

This research reviews the latest technologies in recognizing and distinguishing ASD activity, which has a major role in distinguishing and capturing the movement of every part of the human body and then transferring it to one of the search engines to distinguish, analyze, and determine its type. Several sensors used for discrimination were mentioned and classified, including smartphone sensors or Wearable sensors RGB cameras. Which has several uses, including distinguishing movement, reading the vital characteristics of the body, or locating a person.

This review aims to stress the need for automating, processing, and classification to recognize Autistic children’s activities from a dataset. This paper presents a survey on various Autistic children's activity recognition techniques that were proposed earlier by researchers for better development in the field of monitoring these activities. All these techniques have their advantages, in other words, there is not a single technique that fits best in all categories of Autistic children’s activities. So here we are. We attempt to sum up the methods and techniques used to recognize these activities, it will be helpful to the researchers to understand and compare the related advancements in this area.

In the future, smart medical treatment will usher in a golden period of development, integrating the Internet of Things, cloud computing, artificial intelligence, and other technologies to promote the health service industry into a new period, Healthcare will provide high-quality and efficient and safe medical services for patients, focusing on key construction and continuous improvement in areas such as in-hospital patient information interconnection and sharing, medical big data mining, management of medical treatment, mobile healthcare and family health.

From our study, it is found that the emergence of wearable technology has become a better solution for providing support services to people. However, the system still has some limitations. Some actions have low recognition rates. Further research is needed to improve accuracy and increase the number of activities detected by the system.

From the study of different researchers, it has been found that the use of sensors-based medical gadgets is continuously increasing in the healthcare environment due to which the patient treatment process becomes more dependable and efficient. Patients may get all information regarding their health on their phones and may contact doctors in an emergency and doctors may give prescriptions to patients on the phone from any place. From the analysis of research work that was done by the different researchers, it has been that still there are some major issues with the modern healthcare system like the precision of the system, security, and protection of valuable data, poor data analysis techniques that must be solved soon to promote healthcare service.

One problem highlighted in this work is that medical institutions lack a unified standard among different organizations and regions, and there is a need for improvement to ensure data integrity. As extensive data must be gathered, it will likely make the system rather complicated, which will lead to difficulties in communication and data management. Another problem identified from the research is data identification and analysis within multiple connected devices and platforms. Another solution is to create an open mHealth model that enables doctors and patients to use it easily. A unified platform will allow patients to access telemedicine services and advice, enabling doctors to easily monitor their patient’s health status. Mobile architectures such as mobile health will likely help reduce medical errors, reduce medical treatment difficulty, improve medical services’ timeliness, and provide an economical option for health services.

All the above literature shows good technology usage, but only a few discuss their systems’ capabilities for ensuring privacy and security. The system's adaptability to the person is very important. For instance, fall detection systems suffer from the issues of adapting to every patient because every individual has unique gait values which make it difficult for systems to be designed under a common set of design parameters. Therefore, this issue must be resolved in designing fall detection systems. The other issue with usage is the comfort of the patient. The comfort of a patient can directly or indirectly influence physiological readings to a certain extent. Some systems have very low comfort for the patient. Contactless image-based methods have a lot of developments to be made. For example, motion artifact removal has not been fully solved. In this, patient motion as well as the camera's motion must be addressed. Overall, more studies need to be done to see the acceptance of these technology-based methods within the medical community and patients. Although some trial studies have been done, error correction methods in the technology have not been able to win the medical professionals' complete trust. The review shows that this emerging field of technology is making a substantial impact on society as well as the research community.

Also in this survey, we carried out a comprehensive study of various tools and techniques that can be used in ASD activity recognition which included different machine learning algorithms and neural network techniques. Finally, challenges of ASD activity recognition are also presented. From this survey, we deduce that there is no single method that is best for the recognition of any activity, hence, to select a particular method for the desired application, one needs to consider various factors and determine the approach accordingly. So, despite having numerous methods, some of the challenges remain open and must be resolved.

For future research, some grand areas where wearable sensor-based ASD monitoring researchers can focus are presented as follows:

- Complex high-level activity dataset: The existing wearable sensor datasets are generally focused on activities of daily living, kitchen activities, and exercise, among others. Datasets with more complex activities can be proposed.
- Clustering: Data clustering is the most critical aspect of unsupervised learning. Even though recent researchers are proposing multi-task deep clustering approaches, they have not been able to fully address temporal coherence and feature space locality limitations, which are associated with wearable sensor-based datasets. Future work can investigate the performance of the ensemble of some clustering methods in addressing these issues for unsupervised wearable sensor-based ASD monitoring.

Ultimately, we may conclude that a massive quantity of research has been completed in this area, but many unanswered queries nevertheless exist, together with occlusion, variability in poses, and shortage of effective information.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed to the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare.

APPENDIX

Table 1. Comparison of (Recognized Activities, Application Type, Algorithms, Software, and Sensors) Between Previous Studies

Study No.	Authors and Year	Recognized Activities	Application Type	Algorithms Used	Software's Used	Sensors Used
[20]	Ankush Manocha, Ramandeep Singh, "2019"	Running away. Pulling hairs. Throwing things. Self-punching. Fighting. Head beating.	Monitoring.	3D CNN. LSTM.	Programming language (Python). Integrated Development Environment (IDE). MySQL database.	Wide-range visual sensor.
[21]	Maximilian et al "2019"	Tracking eye movements.	Monitoring.	Convolutional Neural Network (CNN): Called Eye-tracking.	Mobile App.	Camera.
[22]	Seyed Reza Shahamiri, Fadi Thabtah "2020"	Detecting autistic traits (Through the questions directed to the user).	Detection.	Convolutional Neural Network (CNN).	mobile application. Web service. Database. Python. Google's TensorFlow library.	-
[23]	Jing Li, Yihao Zhong, Junxia Han, Gaoxiang Ouyang, Xiaoli Li, Honghai Liu "2019"	Eye Tracking.	Detection.	Long Short-Term Memory (LSTM). Tracking-learning-detection (TLD).	Fast Forward MPEG (FFmpeg).	Camera.
[24]	Sung-In Kim, Eunkyung Jo, Myeonghan Ryu, Inha Cha "2019"	Daily activities (Emotion, Behavior).	Monitoring.	Omni-Track.	Omni-tracker platform. Mobile App.	Embedded in smartphones.
[25]	Vasyl Andrunyk, Olesia Yaloveha "2021"	Emotion.	Monitoring.	Convolutional Neural Network (CNN). Data Flow Diagram (DFD).	Software development kit (SDK).	Camera.
[26]	Marian Binte Mohammed, Lubaba Salsabil, Mahir Shahriar, Sabrina Sultana Tanaaz, Ahmed Fahmin "2021"	-	Detection.	Linear classification techniques: a. Naive Bayes (NB). b. Multinomial Logistic Regression (LR). Instance-based Classification Technique: K-Star classifier. Optimization classification techniques: a. Stochastic Gradient Descent (SGD). b. Sequential Minimal Optimization (SMO). Ensemble classification techniques: a. AdaBoost. b. OneR. c. Random Forest (RF). Neural Network classification techniques : a. Multi-layer Perceptron (MLP). b. Convolutional Neural Network (CNN).	-	-
[27]	Md. Hasan Al Banna, Tapotosh Ghosh, Kazi Abu Taher, M. Shamim Kaiser, Mufti Mahmud, "2020"	Emotions. Some behaviors. Patient's movements and vital signs.	Helping. Monitoring.	Inception-ResNetV2. CNN.	Mobile App.	Accelerometer. Gyroscope. Magnetometer. GPS. Heart rate. Pedometer. Temperature. Camera. RFID.
[28]	Michal T. Tomczak, Marek Wójcikowski, Bogdan Pankiewicz, Jacek Lubinski, Jakub Majchrowicz, Daria Majchrowicz, Annawalasiewicz, Tomasz Kilinski, Malgorzata Szczerska, "2020"	Stress.	Monitoring. Therapy Assistance.	Digital Signal Processing (DSP).	PC application.	Heart rate. Skin resistance. Temperature. Accelerometer.
[29]	Folasade Oluwayemisi Akinloye, Olumide Obe, Olutayo Boyinbode, "2020"	Speech. Happy. Anxiety. Disgust. Attention. Excited. Bored. Sad. Neutral.	Monitoring. Therapy.	Fuzzy Inference System (FIS) in Data Analysis.	Mobile Application. MATLAB server. E-Healthcare module: (relational database management system (RDBMS), XML/ REST, web server, GSM/3G, MD5). Modules integration: (Application Programming Interface (API), JSON). System implementation: (C programming language, JavaScript, CSS 3, PHP, MySQL).	Electrodermal activity (EDA). Speech recognizer.

Study No.	Authors and Year	Recognized Activities	Application Type	Algorithms Used	Software's Used	Sensors Used
[30]	Francesca et al " 2020"	HR and stress response.	Monitoring.	Statistical analysis.	MATLAB. Statistical Package for the Social Sciences (SPSS).	ECG. Respiratory.
[31]	Nastaran Mohammadian Rad, Twan van Laarhoven, Cesare Furlanello, Elena Marchiori, "2018".	Abnormal movements.	Monitoring. Detection.	Normative Probability Map (NPM). Convolutional Neural Networks CNN). Denoising Auto Encoder (DAE).	Mobile App.	Accelerometer.
[32]	Anjum Ismail Sumi, Most. Fatematuz Zohora, Maliha Mahjabeen, Tasnova Jahan Faria, Mufti Mahmud, M. Shamim Kaiser "2018"	Physical location. Vital signs. Sound. Movements.	Monitoring. Assistant.	Fuzzy logic-based expert system.	Mobile App.	GPS. Heartbeat. Accelerometer. Sound.
[33]	Tamara Z. Fadhil, Ali R. Mandeel "2018"	Emotions.	Monitoring.	Statistical and mathematical methods.	NodeMCU (ESP8266) firmware. Message Queuing Telemetry Transport (MQTT) protocol.	GSR.
[34]	Mehmet Baygin, Sengul Dogan, Turker Tuncer, Prabal Datta Barua, Oliver Faust, N. Arunkumare, Enas W. Abdulhay, Elizabeth Emma Palmer, U. Rajendra Acharya 2021"	Autism detection.	Detection.	One-dimensional local binary pattern (1D_LBP). Short-Time Fourier Transform (STFT). lightweight CNNs (MobileNetV2, ShuffleNet, SqueezeNet, ReliefF).	MATLAB (R2020b).	EEG.
[35]	Rugui He "2022"	Emotion.	Monitoring. Therapy	Effective Independence Law (EFI). QR Decomposition. Modal Kinetic Energy (MKE). Modal Strain Energy (MSE). Guyana Model Reduction (GMR).	Apache Tomcat server. Mobile applications. Web-based technologies. Systems programming.	Pulse. Blood pressure. Heart rate. Temperature.
[36]	A. Sivasangari, P. Ajitha, Immanuel Rajkumar, S. Poonguzhali, "2019"	Emotions such as (surprise, smile, sad, happy, ambiguous, neutral, etc.). Face Tracker such as (cheeks, nose, ears, eyes, eyebrows, mouth).	Monitoring. Detection.	Support Vector Machine (SVM). Bayesian network.	Python program. Mobile Application. Web service. ZigBee protocol. FaceTracker.	Camera. EEG.
[37]	Kristine D. et al, "2020".	Movement. Self-injurious behavior detection.	Monitoring. Detection. Care.	K-nearest neighbors (KNN). Support Vector Machine (SVM).	MATLAB Programming language.	Accelerometer. Cameras.
[38]	Vignesh Singh, Rishika Anand "2021"	House Environment.	Monitoring.	-	ThingSpeak. Pushbullet App.	Temperature. Humidity. Environmental gases. Flammable gas. Fire sensor.
[39]	Georgy Lebedev, Herman Klimenko, Eduard Fartushniy, Igor Shaderkin, Pavel Kozhin, Dariya Galitskaya, "2019"	Movements. Facial expressions. deviations in behavior. Phases of sleep. Night rising. Emotions. Sleep. Awakening. Falling. Movement. Epileptic attack. Physiological functions.	Monitoring. Education. Care.	Deep Learning of Artificial Neural Networks. Mathematical and statistical.	PC Application. Mobile Application. Virtual reality (VR) programs. hardware–software system (HSS). Remote Recognition of Emotions. Virtual reality helmet. Virtual reality gloves (joysticks).	• Camera. EEG. • Wearable wrist tracker: (Accelerometer, Gyroscope, Ambient Light Sensor, Indoor positioning tags, Photoplethysmography (PPG): "used to monitor pulse, heart rate variability (HRV), arterial pressure, and mono-channel ECG by measuring changes in blood volume", Skin Moisture. • Body Temperature. • Impedance meter weighing scales. • Indoor environment: (temperature sensor, atmospheric pressure, humidity, insulation (light), electromagnetic radiation, air pollution). • Geotag of the patient: (temperature, humidity, atmospheric pressure, wind speed, solar activity, overcast, magnetic activity, dawn and sunset, air pollution). • iBeacon: indoor technology that allows determining the device location.
[40]	Ameni Kallel, Molka Rekik, Mahdi Khemakhem "2020"	-	Monitoring.	There is no specific algorithm, but they use a business process model and	Hypertext Transfer Protocol (HTTP). MQTT protocol.	Pulse oximeter. Temperature.

Study No.	Authors and Year	Recognized Activities	Application Type	Algorithms Used	Software's Used	Sensors Used
				notation. (BPMN) to model the physical entities as resource elements and the different layers of the system.	Virtualization software. Networking software. Storage software. Monitoring software. Scheduling software. WSO2 CEP. Siddhi. WSO2 DAS. SSO authentication solution. Docker and Kubernetes.	Voice recorder module. Heartbeat. Sound intensity.
[41]	Rajkumar Saini, Pradeep Kumar, Barjinder Kaur, Partha Pratim Roy, Debi Prosad Dogra, K. C. Santosh."2018"	Boxing. Eating. Bending. Dancing. Read. sitting. Clapping. Jumping. Sit still. Hand wave. Kicking. Sitting. Phone call. Read standing. Typing. Paper toss. Running. Write sitting. Push/pull. Standing. Walking. Thinking. Stand still. Write standing. Drinking.	Monitoring.	Bidirectional long short-term memory neural network (BLSTM-NN).	Xbox 360 Software Development Kit (SDK).	Kinect sensor: (Depth-sensing camera, Infrared projectors, Microphones).
[42]	Salma Kammoun Jarraya, Marwa Masmoudi, Mohamed Hammami "2020"	Emotion.	Detection.	Feed Forward (FF). Cascade Feed Forward (CFF). Recurrent Neural Network (RNN). Long Short-Term Memory (LSTM).	Software Development Kit V2.0. (SDK). API Face Basics. Form Emotion Application.	Kinect sensor.
[43]	Hoang-Long et al "2019"	Emotion. Vocal prosody. Gaze. Movement. Facial expression. Tracking. 3D moving skeleton.	Therapy.	• Supervised descent method for locating feature points on the face. • Object pose-estimation method for calculating the head pose. • Hierarchical adaptive-convolution method for localizing iris centers. • Linear support vector machine (SVM) classification algorithm for recognizing human actions. • Frontalization method for recovering frontal facial appearances from unconstrained non-frontal facial images. • Local binary patterns feature-extraction method applied to three orthogonal planes to represent facial appearance cues. • Blob-based Otsu object-detection method for object tracking. • Gaussian mixture probability hypothesis density tracker for detecting and tracking objects in real-time.	Kinect Software. PC App. Mobile App. Robot platform.	Kinect. Microphone. (RGB) Camera.
[44]	Fady Alnajjar et al "2020"	Emotion (happy, sad, angry, surprised, neutral). Face detection. Voice detection.	Therapy. Diagnosis.	Haar classifiers: a machine learning algorithm used for object detection.	Aldebaran/Softbank NAO robot. Emotions Selector mobile application. PC program. TCP socket connection. Python module.	Mobile camera Mobile Mic.

Table 2. Comparison of (Devices, Data Type, Notifications, Accuracy, Future Works) Between Previous studies

Study No	Devices Used	Data Type	Notifications	Accuracy	Future Works
[20]	Wide Camera.	Video Frames.	Yes.	92.89%	More training samples will be collected to make the system more sensitive to every possible physical irregularity. The refined annotated datasets will be used to re-train the system to observe the increment in the classification performance.
[21]	Mobile Camera.	Video frames.	-	74.7%	Improve the robustness of the system to roll the angle of the phone and distance between the user and the screen to allow deployment in a home setting.
[22]	-	Questionnaire.	-	97.95%	The proposed AI screening system can be expanded to possibly explore advanced deep learning schemes that can detect new unconventional features of autism from complex features. Studies can investigate cluster analysis to identify endophenotypes. assess the role of development to help the diagnosis (since some features are more important for children or adults). Refine the prognosis and the therapeutic strategy.
[23]	Camera. PC.	Video Frames.	-	92.6%	Extend the video dataset and collect multimodal data for extracting more discriminative features from the actions and behavior of ASD children and TD children. Resort to more advanced deep learning technologies for classification tasks.
[24]	Smartphone.	Analog signals. Digital signals.	-	-	Investigate the expected role of caregivers and therapists in the process and the extent to which they should be involved in the design and use of self-trackers and the data reflection process. Broad-scale study regarding how individuals with neurodevelopmental disorders engage in self-tracking.
[25]	Camera.	Video frames.	-	-	-
[26]	-	Number. String. Boolean. Integer. Binary	-	100%	Work with a larger dataset and inflate its accuracy. Introduce a new screening method for better performance.
[27]	Smart wristband. Monitor. Camera. Radio Frequency Identification (RFID). Wi-Fi module.	Images. Analog signals. Digital signals.	Yes.	78.56%	A more compact design and features like augmented reality will be incorporated. A human activity recognition model will be incorporated.
[28]	Wearable device (wristband).	Analog signals. Digital signals.	-	-	-
[29]	Wearable device (Arduino Mega Microcontroller). Liquid Crystal Display (LCD) screen. Bluetooth. Buzzer. Electrodermal (ED). Data cable. Smartphone/Tablet. Database Server. Wi-Fi module.	Analog signal. Digital signal.	Yes.	92.07%	More physiological devices (heart rate, ECG, PPG). Other modalities to capture the speech, linguistics, postures, and facial expressions of ASD children.
[30]	Wearable device: (Heart rate, thoracic belt with highlighted electrocardiograph, wireless device embedded in the belt, USB transceiver). PC.	Analog signals. Digital signals.	-	The percentage of variance was higher (21%)	Data collection is needed to confirm preliminary results. Characterize physiological patterns linked to different behaviors and emotional states and monitor the outcome.
[31]	Wearable device.	Analog signals.	-	-	Use generative alternative models instead of DAE such as variational autoencoders, adversarial autoencoders, or generative adversarial networks. Use the proposed framework for implementing a real-time Mobile application for abnormal movement detection. Implementing a real-time mobile application.
[32]	Wearable device (smartwatch).	Analog signals. Digital signals.	Yes.	89%	Study many children of various ages. Detailed study on the performance evaluation of the defined fuzzy sets and fuzzy logic.
[33]	PC or Smartphone. Router. Broker Server. NodeMCU (ESP8266). Galvanic Skin Response (GSR).	Analog signals. Digital signals.	-	-	-
[34]	PC.	EEG signals. Spectrogram Images.	-	96.44%	Use our model for the early detection of autism in a clinical setting.
[35]	Wearable device. General Packet Radio Services (GPRS). WIFI module. PC. Smartphone. Server.	Analog signals. Digital signals.	-	-	Conduct long-term observational research with large samples. Collect more relevant information. Establish a more complete evaluation mechanism. More detailed coding analysis of the experimental results.
[36]	Wearable device (Raspberry Pi). Web camera. Wi-Fi module. 3G or 4G cellular network.	Images. Analog signal. Digital signal.	Yes.	86%	Activate validation data obtained from the voice. Human facial recognition.
[37]	Wearable device (tri-axial accelerometers). Cameras.	Analog signals. Digital signals. Video frames.	-	At the group level 97% At the individual level 93%	Should include data collected in diverse locations. Methods should be extended to further consider real-world applications. Could include additional modeling techniques, such as sliding windows. An output of > 60 decisions could overwhelm caregivers with unnecessary information.
[38]	Arduino UNO. Wi-Fi. Buzzer.	Analog signals. Digital signals.	Yes.	-	Add more sensors like ultraviolet sensors and other sensors to detect the various parameters of the environment. Can analyze the data collected from this proposed system by using machine learning techniques. Can make this system much cheaper by using the processing unit which has an in-built Wi-Fi module so that the

Study No	Devices Used	Data Type	Notifications	Accuracy	Future Works
					cost of the extra Wi-Fi module reduces.
[39]	Camera. Wearable wrist. MMD (Medical Monitoring Devices). Computer/Smartphone/Tablet. Indoor environmental sensors. Wi-Fi, Cellular network. Bluetooth.	Video Frame. Analog signals. Digital signals.	Yes.	-	-
[40]	Sensor. Actuator. Reader. Smartphones. Laptop computers. Tablets. Smartwatches. Bracelets no-mobile devices (Arduino or Raspberry). Camera. Wireless network (4G/5G and Wi-Fi). Wired networks.	Images. Voice. Analog signals. Digital signals.	-	-	Improve our data management system while making it more flexible according to the material and human resources as well as to the latest data collected from the literature and the experience of countries that faced this disease. Integrating other sensors such as movement, temperature, and GPS sensors. Implement a deep learning approach to improve the data management system.
[41]	Kinect. PC.	3D pictures for skeletal.	-	70.72%	Exploring novel features and multi-classifier fusion-based approaches.
[42]	Kinect camera. PC.	Video frames.	-	85.8%	Explore the deep learning algorithms based on frames and videos. Take advantage of the detected skeleton features to analyze and recognize abnormal autistic activities during a meltdown crisis.
[43]	NAO Robot. Tablets.	Video frames. Images. Voice.	-	63.71%	Increase the level of robot autonomy in robot-enhanced therapy (RET) research. In future applications and based on a set of rules, it would act as an alarm system that is triggered when the robot detects technical limitations and ethical issues.
[44]	NAO Robot. Smartphone. PC. IP camera. IP microphone Wi-Fi module.	Video frames. Voice data. Numerical value.	-	82.4%	Increase the assessment accuracy and further enhance the patient’s engagement with the robots. Use multiple cameras. Increase the number of patients.