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A Review of Early Detection of Autism Based on Eye-Tracking and Sensing Technology

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Abstract—**The current paper is a review of eye-tracking and sensing technologies that detect and monitor Autism Spectrum Disorder (ASD). Nowadays, the biggest challenge is the detection of autism before the age of 36 months. The diagnosis of autism in the early stage of life can help autistic children improve their social communication and quality of life. Therefore, the technology can support psychologists to get the right diagnoses of autism and accordingly the autistic children can get appropriate treatment for their condition. In this review, the focus is on eye-tracking and sensing technologies. The autistic children have different attentional biases in social interactions that can be measured by eye-tracking technology. Moreover, the autistic children have some signs that can be easily detected by using the sensing technology such as hand flapping, body rocking and motion trackers.**

Keywords-Autism Spectrum Disorder (ASD); Typical Developing (TD); Eye Tracking; Sensing Technology; Hand Flapping; Motion Trackers, Machine Learning.

I. INTRODUCTION

The using of the technology to diagnose ASD is rarely utilized in the past but, recently the most powerful tools to detect autism are eye-tracking and sensing technologies. Several studies found the children with ASD don't use eye contact during the social interaction compared to the children with normal deployment [1]. So eye-tracking technology can support the measurements on eye movements which are impossible to assess with the naked eye (e.g. saccades and smooth pursuit). As well as the sensing technology used to detect the abnormal behavior of the children such as body rocking, hand flapping, …etc.

The diagnosis of ASD is very difficult as it needs for a long time to observe the behavior of the ASD children. ASD average is 1 in every 88 people that make families and governments worried about how to diagnose ASD in the early stage of the children's life [2]. In this review, this paper studies the use of eye-tracking and sensing technology to detect autism early in life. According to previous studies, most eye-tracking and sensing technology researchers have concentrated on quantifying differences in social attention and behavior between samples with ASD and TD children.

The aim of studying ASD is to help Autism specialists to reach the right diagnosis of ASD in the early stage of life. So 80% of the children with autism who were diagnosed at an early stage succeeded in improving their level of communication [2].

The eye-tracking technique allows psychologists to diagnose ASD by monitoring eye movement for a short time and analyze the eye fixation of ASD [3]. There are different types of sensors used to identify the abnormal behaviors that can help to reach the right diagnose of ASD.

This review of previous studies is based on two technologies for examining the autistic children, namely, Eye-Tracking technology and sensing technology between 2013 to up to the publication of this paper. There are also numbers of technologies and methods used by some researchers such as some questionnaires and developmental tests, EGG, MRI and screening and diagnostic-based on videos.

II. RELATED WORK

A. *Eye-Tracking Technology*

Most of the studies in this review used eye-tracking technology to collect eye fixation and eye motion while children are watching the visual stimuli to detect autism by comparing ASD and TD children. The experiment room should be dark and soundproof. The child is seated in his parent's lap in front of the screen for watching the visual stimuli, there are two types of stimuli, dynamic and static visual stimuli. The researchers used Tobii eye-tracking devices to record the eye-tracking of the children for further processes.

Almourad, M. B., Bataineh, et al.[4] utilized eye-tracking technology in order to compare and analyze autistic children and typically developing children based on gaze patterns. The data was collected from 65 participants, 34 with ASD children and 31 TD children. The average age was 8 years old. They collected the data by Tobi X2 eye tracking. The children were seated in front of the eye tracker device and watched the objects (tomato, football, banana, tomato and a human child's) and the experimenter recorded their eye fixation. In this study, they found children with autism less fixation on eyes and expressed interest in looking at the mouth than the typically developing children.

Wan, G., et al. [5] suggested a method for earlier detection of autism. The dataset was 37 with autism and 37 typically developing children between 4–6 years old. The experimental stimuli utilized the SMI RED250 portable Eye Tracking system. The 10-second silence video clip of an Asian female speaking showed to the children. The ten AOI were tested: background; body: shoulders, neck, chest and hair, outer-face: the face area excluding the mouth, nose, and eyes, nose, mouth, eyes, person: body, hair, face, face: outer-face, eyes, nose, and mouth. The classification accuracy was 85.1%, sensitivity of 86.5%, and specificity of 83.8%.

Del Bianco, T., et al. [6] investigated the interaction of the ASD with face and eyes. The data was collected from 20 adults with ASD and 24 young adults TD, by using T120 eye-tracker. The stimuli used 24, 10-s videos, there are some questions that can be answered by participants after watching the videos he/ she answered by using the keyboard with the direction. For example, they were asked to find the object that is located on the body of the model the question (Who got the pen?) the participants answered the questions by indicating the side of the persons who wore a pen on her/his body then pressing A if the model is in the central or L for left and R (right) direction. They analyzed the fixation on AOIs, face, the body of the models, background and central model. The result showed the ASD children have less fixation on the face.

Pierce, K., et al. [7] proposed eye-tracking patterns to identify the ASD child in the early stage of life. The participants were 334 children from 6 distinct groups (115 ASD, 20 ASD-Features, 57 DD, 53 other, 64 TD, and 25 Type SIB). Data were collected by using Tobii T120 eye-tracker device. The children were presented with a movie consisting of AOIs that consisted of DGI and DSI images that were positioned side-by-side in which scenes changed simultaneously. The ASD sensitivity was 21%, specificity was 98%, and the positive predictive value was 86%.

Billeci, L., et al. [8] described the differences in the visual patterns of children with autism and typically developing children while they are responding to joint attention and initiating joint attention tasks. Data were collected from 17 children with autism and 15 typically developing children. In this paper, they used the SMI Eye Tracker device. They found that children with autism have different visual patterns than typically developing children.

Falck-Ytter, T., et al. [9] studied how autistic children looked at other children. The participants were 39 with ASD and 28 TD. The experimenter showed to the TD and ASD children a short video clip of two young children playing with a toy with nonverbal communication. The Tobii T120 used for recording the eye-tracking. The result of the classification accuracy was excellent 0.91

Kwon, M. K., et al. [10] examined eye-region fixation levels for 385 children (143 with ASD, 242 TD) between 11–47 months. Tobii T120 eye-tracking was used for recording eye movement. The child seated in his parent's lap and watched a 43-second video of the woman speaking some common words with hand gestures. In experiment 1,2, they used statistical analysis to collect the number of fixations in each part of the video such as (eyes, face, nose, mouth, body, background). The result showed the ASD more fixation on a low part of the women (mouth, body).

Duan, H., et al.[11] developed a dataset of 14 autistic children and 14 typically developing by recording their eye movement data. In this study, they divided the 300 images (animals, buildings, objects, natural scenes…) into 10 sessions by showing 30 images in each session and each image was presented in the screen for 3 seconds than one-second gray screen and so on. Tobii T120 Eye Tracker was used to record eye movement. The analysis of data collected from the fixation position they set 1 in when the map is available otherwise 0, for both ASD and TD. The result of the study found the ASD have more fixation in the hand and objects, the TD more fixation in faces.

Seepold, R., et al.[12] developed a model to test the difference between children with autism and typically developing children. The fixation point was collected from 20 children with ASD and 19 TD. The dataset consists of 700 images that were shown to the children. Each image is shown in 1 second. SVM classification was used to analyse the eye-tracking data based on a three layered architecture, pixel-level object level, and semantic-level feature as well as the image center and the background. They found people with ASD more interested to look at the center of the image more than people with TD. The result of the classification is accuracy 0.936

Lee, M., et al.[13] tried to determine if there are similar patterns of parents that might impact the skills of their children. They tested narrative ability in ASD and their parents through differences in structure and emotional content by the eye-tracking. Participants from children were 37 with ASD and 38 TD and without a family history of ASD, Participants from parents were 151 with ASD history in their family and 63 parents without a history of ASD. The AOIs were face and body regions for each character in images and the recording of the eye movement used Tobii T60 series eye tracker. They analyzed data by calculating the fixation data in each AOIs. The result indicates the ASD may get influenced by genetic that affects language skills.

Sabatos-DeVito, et al.[14] disengaged and oriented attention in children with ASD, relative to DD and TD peers. The Participants were (ASD =19, TD= 20, DD =11) at ages 4–13 years. Eye movements were recorded by a Tobii x 120 Eye-Tracker. They also added a web camera to capture faces and looking behavior. The stimuli consisted of the non-social object with interesting visual and auditory qualities. The child seated on his parent's lap with 60 cm distance from the Tobii TX300 eye tracker device and the experimenter showed the stimuli. Eye-Tracking data extraction was converted to CSV for analysis the number of the fixation on the x/y of the screen. The result of disengagement appears in all the groups during the dynamic stimuli compared to static stimuli, they found ASD groups were slower in disengagement.

Alvares, G. A., et al. [15] developed and tested the efficacy of the new method to attract the attention of autistic children to faces. The participants were 66 with ASD between 5 and 12 years old. The stimuli include social and non-social images for the eye-tracking tasks and game called “Frankie and Friends” to attract the attention of the autistic children to faces. The result showed the children in the training group significantly increased the percentage of engagements to faces relative to objects after training.

G., Bölte, S. et al. [16] tested the joint attention according to the follow gaze and head direction in the autistic children. The participants were 64 children between 10-month-old; 46 with ASD of high-risk and 17 with ASD of low-risk. A Tobii TX300 device was used for eye tracking. The participants watched an experimenter gaze at objects in the surroundings. The performance was compared across two conditions: one who moved both eyes and head to the objects and the other who moved his eyes only. The result of the group with ASD of high-risk showed followed gaze by movement in the Eyes and Head, the group of ASD of low-risk showed the movement of eyes only.

Bataineh, E., et al. [17] studied an eye-tracking analysis to recognize the visual behavior and pattern of TD and ASD children through the stimulus of social interaction. The data was collected from Sixty-five children, 34 with ASD and 31 with TD, by using Tobi X2 model to record the eye-tracking. The stimulus were groups of images (banana, face, tomato and football,) to test the eye-tracking of children. The result showed that TD children’s eyes fixated on the face more than ASD.

KB, P. R., et al.[18] designed Eyegaze-sensitive Virtual reality based social communication Platform. The system aims to proof how the ASD child does social communication skills. They designed VR-based Task Presentation of virtual environment e.g., home based birthday party …etc. The participants were two with ASD and two with TD. The children were seated in front of the screen and wore eye tracker goggles to watch the stimuli. The experimenter calculated the number of fixations in two AOI face and environment. They found the ASD children got less number of the fixation on the face, ASD1 30.97%, ASD2 26.16% and TD1 79.93%, TD2 75.27%.

Frazier, T. W. ., et al. [19] aimed to improve and validate eye tracking-based measures for the evaluation of Autism spectrum disorder and determined the level of autism symptom. They used SMI Red250 remote eye tracker for data collection. Participants were exposed to a five-minute video that consisted of 44 dynamic stimuli and the experimenter recorded their eye-tracking. They used statistical analysis of gaze patterns. The result showed ASD diagnosis was accuracy 0.86, 95%.

Wagner, J. B., et al. [20] tested the behavioral, neural and autonomic correlates of face emotional for people with ASD and TD by utilizing eye-tracking and event-related potentials (ERPs). The eye-tracking and electroencephalogram (EEG) were used in this study. The participants were 18 with ASD and 20 TD. The eye-tracking stimuli is composed of photos of five female faces, each showing fearful, happy, or neutral expressions. The Participants were seated on a chair in front of Tobii T60 monitor and the photos viewed for 5 second each. They found that there was a relation between gaze behavior and emotions.

Ahtola, E., et al. [21] used eye-tracking to improve the responses to complex visual stimuli during EEG in infants. The data was collected by using Tobii T120 from 39 male; 17 females of normally developing infants. The stimulus consisted of wave gratings with a spatial frequency of 0.45 degree. The child seated in the parent’s lap and during the view of the visual stimulus, eye tracking, and EEG recorded parallelly. The result of 39 healthy children after statistical analysis ($p<0.01$) responses to the orientation reversal were 92%, global form was 100% and global motion was 95% of stimuli.

In this section, studies that used machine learning techniques for detection and classification of autism were reviewed.

Wei, W., et al.[22] proposed a new method using multi-level features and deep supervision to detect the eye fixation of ASD children and regions in images. The applied CNN on MIT1003 Saliency of ASD eye-tracking dataset that consisted of 300 images for ASD and TD. The result of the accuracy is 0.818%.

Jiang, M., et al. [23] built a model based on the machine learning to compare between the eye fixation of ASD and TD. They used the data collected by Shuo Wang; et al. in their research “Atypical Visual Saliency in Autism Spectrum Disorder Quantified through Model-Based Eye-Tracking”. The sample was taken from 20 high-functioning adults with ASD and 19 TD. They used DNN and SVM for classification of the images. The best performance was DNN with 0.92% accuracy.

Duan, H., et al.[24] used the saliency prediction for children with autism (SPCA) database that consisted of 500 images of 13 children with ASD. They developed the DNN model and compared the result of five Algorithms; Salicon, SalGAN, Mlnet, SAM-VGG and SAM-ResNet. Tobii T120 was used to collect the data. The experiment was divided into 10 sessions and the 50 images were randomly shown in each session to the children and recorded their eye-tracking. They found the best performing in two algorithms were SalGAN in the healthy group the best result was AUC 0.8843 and SAM-VGG in the group with ASD the best result was AUC 0.8178.

Tao, Y., et al. [25] used CNNS for ASD and TD classification based on the scanpath of the fixation point. They used a dataset provided by Saliency4ASD grand challenge which consisted of 300 images collected from 14 ASD and 14 TD. The result of the classification was 74.22% accuracy.

Jiang, M., et al. [26] investigated the typical visual attention of people with ASD and TD using a facial emotion recognition task. The participants were 23 with ASD and 35 TD between 8–17 in age. The Stimuli video consisted of various facial emotional expressions and the recording of the eye-tracking done by using Tobii Pro eye tracker. The machine learning method was used to classify how they looked in the emotion recognition task. They found a significant difference between groups in Eye movement patterns. The result of using a deep neural network achieved an 86% classification accuracy.

Dalrymple, K. A., et al.[27] used machine learning to classify two groups of the children, 37 children in 18 months-old and 36 children in 30 month-old. The experimenter showed static Stimuli to the children and used a Tobii TX300 eye-tracking device to record the eye movement. They used Deep learning classification according to the number of the fixation maps. The result showed the children of ages 18 months more interested in the dark region and the children of 30 months more interested in the bright region. The classification was 0.70 accuracy.

Król, M. E., et al. [28] proposed a new approach of quantifying the utility based on visual information extracted from facial stimuli for emotion recognition. The system based on the recording of eye-movements of 21 autistic children. The Stimuli of 36 photos of the male and female were shown to the children. SMI RED250 Mobile was used to record the eye-tracking. They designed a system showing the image after that question appeared on the screen such as "what is the emotion in the face expression?" and "which feature is wider " the choices of the question-answer were there. This study found that ASD group has more fixation on lower areas of the faces and fixated on the eyes was less than the TD group.

B. Sensing Technology

The use of wearable sensors in healthcare has increased in recent days. The wearable sensors are able to monitor the physiological abnormal behaviors such as hand flapping, body rocking, motion trackers. There are various types of sensors such as Wireless Body Area Network (WBAN), smartwatch, heart rate and pulse sensor [29].

Alwakeel, S. S., et al. [30] proposed a system that can detect the abnormal behavior such as gesture and motion of the ASD child and sent an alarm to his family using wireless sensor networks (WSNs). The EZ430-Chronos accelerometer sensor wore on the patient's wrist, then used ANN Classifier with statistical features of hand hitting against the ear, arm flapping, hand rotation up and hand rotation down. They tried three types of classification and the best result was from the NN with an accuracy 99.127%.

Min, C. H. [31] used the wearable sensors to collect the data from 4 children with ASD and 4 TD. The children wore the sensor on their wrist to detect the flapping, punching and rocking actions recorded from the sensor placed behind the back below the neck of the child. Video camera with a microphone also used in this study. The model achieved 91.5% of classification.

Rad, N. M., et al. [32] developed an application using deep learning for stereotypical motor movement detection of ASD children using the wearable sensor. Data was collected by EXLS3 sensor from 4 TD people while preforming normal activities in the work and 6 with ASD while being classroom environments. The sensors wore on the left and right wrists and torso. They used CNN classification. The application can detect abnormal movements and send an alert to a therapist, caregiver, or parents.

Coronato, A., et al. [33] proposed a method to detect the stereotyped motion of ASD. They used eZ430-Chronos accelerometer to collect data. The patient wore an accelerometer in his wrist and the accelerometer sent the data to the system by Wi-Fi. The accelerometer consisted of a pressure sensor and a 3D-axis accelerometer for motion sensitive control. The system detected the hitting against the ear, arm flapping, hand rotation up and hand rotation down. The accuracy of using ANN classifies off-line 99%, and on-line classifier was 92%.

Gilchrist, K. H., et al. [34] detected the common motor motions using accelerometers affixed to the body. A rocking detection using Zephyr sensor placed on the chest and shirt collar. The hand- flapping , used Axivity sensors on the left and right wrists. Twenty participants were tested in this study. The method achieved the sensitivity for body rocking 80% and 93% for hand flapping.

Rodrigues, J. L., et al. [35] developed a system to detect stereotyped behaviors by recording the hand flapping movements based on EZ430-CHRONOS sensor that was placed on the wrist. The algorithm based on statistical methods was used to calculate the hand flapping movements. The system was tested with seven healthy adults. Then, it was used with four typically developing children and with ASD five children. The system has shown high performance.

Gong, Y., et al. [36] proposed an automatic ASD screening based on analysis of a child's vocalizations captured by Smart Devices at home. The application works on an (iOS) Apple iPod Touch devices. It recorded the vocalizations and sent them to the cloud. The data was collected from 27 subjects; 9 TD and 18 ASD. The result of the classification of ASD and TD was 0.87.

Rad, N. M., et al. [37] proposed automatic stereotypical motor movements detection systems for autism using deep learning architecture. In this study, they used a 3-axis accelerometer worn on the right arm of ASD children to capture their repetitive behaviors. Data was collected from 6 autistic using three 3-axis accelerometer sensors then CNN algorithm was applied. They proved the CNN can be used to detect the stereotypical motor movements.

Amiri, A., et al. [38] used smartwatch system to recognize and monitor the ASD behavior activity which might be dangerous to the person. The smartwatch recorded the motion data and sent it to the cloud for processing. The data was collected from 12 TD and 2 ASD. They used the machine learning classification of decision trees to detect and classify the repetitive behaviors. The algorithm achieved 96.7% accuracy in the recognition of autistic behaviors.

Sarker, H., et al. [39] used a smartwatch to detect stereotypical motor movements. The data was collected from the six IBM employees acting the behavior similar to autistic children such as (head banging, hand flapping, and repetitive dropping). The smartwatch was connected to Android tablet using Bluetooth to transmit data to the remote server. After the statistical analysis, the result of the classification is 92.6% accuracy.

Airij, A. G., et al. [40] developed a system to detect the stress in autistic children based on the heart rate. They used a pulse sensor and GSR sensor, with the Arduino board having ATMega2560 microcontroller. The participants in this experiment were 35, among which 19 Male and 16 Females.

The result of testing the system is able to detect the various stress levels.

Rihawi, O., et al. [41] investigated the behaviors provided by a benchmark dataset for researchers. The data were captured by Kinect sensor. It consisted of static behaviors such as hands on the face, hands back, etc. and dynamic behaviors such as rocking, flicking, etc. They used dynamic time warping distance to detect a likeness between two actions.

Ward, J. A., et al. [42] proposed a method of using a wearable accelerometers E4 sensor to measure the non-verbal communication skills of autistic children in theatre with a group of people. The participants were 10 children between 8 and 16 years old. They found that it is a new method that can be used in the school to monitor the development of children with ASD. The result of the method can help to provide appropriate healthcare for ASD.

Goodwin, M. S., et al. [43] extended to previous research they published under the title "Detecting stereotypical motor movements in the classroom using accelerometry and pattern recognition algorithms". They used three wireless accelerometers sensors worn in hands and around the chest. The data was collected from the same 6 participants with ASD. They compared two separate experiments in 3 years and compared two types of classification, Support Vector Machine and decision tree. The accuracy of overall result was between 81.2 to 99.1%.

Großekathöfer, U., et al. [44] compared the results of their study and (Goodwin, M. S,2014) study[43]. They used the same dataset collected by Groden Center. The participants were 6 autistic children with 12 and 20 years. They used three wireless accelerometers sensors worn in hands and around the chest. They compared the result of Decision Tree (DT) and Support Vector Machine (SVM) classification; SVM classifiers of Goodwin was 0.82 accuracy, in their study was 0.86, DT classifiers of Goodwin was 0.76 in their study was 0.83.

Lanini, M., et al. [45] designed a prototype of a sensorized toy (airplane) to detect the movements and orientation for observation of the young patients. The prototype of the system consists of hardware: Arduino, two 3 Axis accelerometer sensors in the airplane and Raspberry PI device as a server. They created a database to store data. The data could be accessed remotely by medical specialists through a web-based dashboard. They tested two children between the ages of 8 and 9 years with ASD.

Moradi, H., et al. [46] designed a novel intelligent toy car for autism testing. The car consists of the ADXL345 accelerometer sensor with ESP8266 (IoT) board, ADXL345 to record the behavior of the children while playing with the car. Each child had 5 minutes, the data was recorded and sent to the computer for further processing. This system was tested on 25 children with ASD and 25 TD. The classification of Support Vector Machine (SVM) was with 85% correct classification rate, 93% sensitivity and 76% specificity.

Cabibihan, J. J., et al. [47] detected the abnormal behavior of children with ASD. This study discussed various sensors it can be used to detect that behavior. They tested a 10-year-old boy with ASD by a wearable sensor E4 wrist band sensor to detect the changes in the sweat rates and heart rate sensor and a 3-axis accelerometer for movements. They detect increased acceleration due to the movement of the hands as the child covered his right ear.

Heathers, J. A., et al. [48] compared the stereotypical body rocking and hand flapping to heart rate. The data was collected from 10 young adults with ASD during normal activities by using a video camera and a three-axis accelerometer and LifeShirt to collect the data. They found that there is a relation between the stereotypical body rocking and hand flapping and heart rate in people with ASD.

Alam, M. E., et al. [49] proposed IoT-BRB system to assess ASD by using three types of sensors; Ear-clip heart rate sensor, EMG (Electromyography) sensor and microphone. They collected physiological and behavioral data from 10 ASD subjects. Data processed and classified. They compared their system result and the assessment of the expert. They found the performance of BRB systemhigher than that of the expert.

Rodriguez, J., et al. [50] proposed a new predictive tool to collect information from multi-sensors. Using four types of sensors TICC2650 to measure the Room temperature, Kinect sensor for Head, chest, and limbs position and orientation, Mindwave Attention and meditation levels, Oculus VR go head position and orientation, and Apple Watch for heart rate pulse with gateways that receive all the information that received through Wi-Fi to the database. In the end, they collected and managed all the data from the number of nodes to predict the scalability and the interference influence on a network.

Mohammadian Rad, N., et al. [51] proposed a method for detecting and monitoring abnormal movement behaviors in patients with Parkinson's disease and individuals with Autism using wearable sensors. They applied CNN on two datasets Freezing of Gait dataset and SMM dataset. The SMM dataset contains accelerometer recordings from 6 individuals with ASD for body rocking and hand flapping. Daphnet Freezing of Gait dataset (FOG) was collected from 10 Parkinson's disease patients who wore three 3-axis accelerometer sensors on their shank, thigh, and belt. They compared the result of SVM and Deep Normative Modeling. Their proposed method got high performance.

Saini, R., Kumar, P., et al. [52] proposed the Kinect sensor-based interaction monitoring system between two persons using the (BLSTM-NN). Kinect sensor was used to record data with Xbox 360 Software for tracking the humans in the area of the sensor. They tracked the 3D skeletal view of two persons while interacting with each other by performing different activities. The data was collected from 10 volunteers by recording all twenty joint positions structure to monitor the type of activity. In this study, the maximum accuracy was 70.72%.

Ahmed, I. U., et al. [53] proposed a system to monitor and track autistic children. The system components are Pulse sensor, temperature sensor and GIS, GSM SD modules. The system monitored the autistic patient health and sent an alert to his parents if there is an abnormal condition detected as well as the location of the children. All information is sent to the smartphone application.

III. CONCLUSIONS

This review paper has covered eye-tracking and sensing technology studies of autism detection, most of the studies reviewed are on eye-tracking technology. Studies collected the eye fixation and eye-tracking maps while watching the visual dynamic stimuli or static stimuli. The studies compared two groups of children, with autism and typically developing ones. Regarding the methods used in the reviewed studies, some used statistical analysis of the eye-fixation numbers and the other studies used machine learning for eye-tracking heat maps. They found the autistic children are less interested in the faces and eyes while the typically developing as well as the ASD focused on the mouth, the body and background.

In this study, the researchers also reviewed the use of wearable sensors for autism detection. Most of the studies detect the abnormal behavioral such as hand flapping, body rocking, motion trackers, by using various types of sensors such as Wireless Body Area Network (WBAN), smartwatch, heart rate, and pulse sensor. Most of the studies compared two groups of children with ASD and TD by using machine learning techniques.

REFERENCES

[1] Vargas-Cuentas, N. I., Roman-Gonzalez, A., Gilman, R. H., Barrientos, F., Ting, J., Hidalgo, D., ... & Zimic, M. (2017). Developing an eye-tracking algorithm as a potential tool for early diagnosis of autism spectrum disorder in children. PloSone, 12(11), e0188826.

[2] Vargas-Cuentas, N. I., Hidalgo, D., Roman-Gonzalez, A., Power, M., Gilman, R. H., & Zimic, M. (2016, October). Diagnosis of autism using an eye tracking system. In 2016 IEEE Global Humanitarian Technology Conference (GHTC) (pp. 624-627). IEEE.

[3] Carette, R., Cilia, F., Dequen, G., Bosche, J., Guerin, J. L., & Vandromme, L. (2017, October). Automatic Autism Spectrum Disorder Detection Thanks to Eye-Tracking and Neural Network-Based Approach. In International Conference on IoT Technologies for HealthCare (pp. 75-81). Springer, Cham.

[4] Almourad, M. B., Bataineh, E., Stocker, J., & Marir, F. (2018, March). Analyzing the Behavior of Autistic and Normal Developing Children Using Eye Tracking Data. In International Conference on Kansei Engineering & Emotion Research (pp. 340-349). Springer, Singapore.

[5] Wan, G., Kong, X., Sun, B., Yu, S., Tu, Y., Park, J., ... & Lin, Y. (2019). Applying Eye Tracking to Identify Autism Spectrum Disorder in Children. Journal of autism and developmental disorders, 49(1), 209-215.

[6] Del Bianco, T., Mazzoni, N., Bentenuto, A., & Venuti, P. (2018). An investigation of attention to faces and eyes: looking time is task-dependent in Autism Spectrum Disorder. Frontiers in psychology, 9, 2629.

[7] Pierce, K., Marinero, S., Hazin, R., McKenna, B., Barnes, C. C., & Malige, A. (2016). use reveals abnormal visual preference for geometric images as an early biomarker of an autism spectrum disorder subtype associated with increased symptom severity. Biological psychiatry, 79(8), 657-666.

[8] Billeci, L., Narzisi, A., Campatelli, G., Crifaci, G., Calderoni, S., Gagliano, A., ... & Raso, R. (2016). Disentangling the initiation from the response in joint attention: an eye-tracking study in toddlers with autism spectrum disorders. Translational psychiatry, 6(5), e808.

[9] Falck-Ytter, T., von Hofsten, C., Gillberg, C., & Fernell, E. (2013). Visualization and analysis of eye movement data from children with typical and atypical development. Journal of autism and developmental disorders, 43(10), 2249-2258.

[10] Kwon, M. K., Moore, A., Barnes, C. C., Cha, D., & Pierce, K. (2019). Typical Levels of Eye-Region Fixation in Toddlers With Autism Spectrum Disorder Across Multiple Contexts. Journal of the American Academy of Child & Adolescent Psychiatry.

[11] Duan, H., Zhai, G., Min, X., Che, Z., Fang, Y., Yang, X., ... & Callet, P. L. (2019, June). A dataset of eye movements for the children with autism spectrum disorder. In Proceedings of the 10th ACM Multimedia Systems Conference (pp. 255-260). ACM.

[12] Seepold, R., Lebedev, G., & Madrid, N. M. (2019, August). Telemedicine system model to help children with autism spectrum disorders. In AIP Conference Proceedings (Vol. 2140, No. 1, p. 020064). AIP Publishing

[13] Lee, M., Nayar, K., Maltman, N., Hamburger, D., Martin, G. E., Gordon, P. C., & Losh, M. (2019). Understanding Social Communication Differences in Autism Spectrum Disorder and First-Degree Relatives: A Study of Looking and Speaking. Journal of autism and developmental disorders, 1-14.

[14] Sabatos-DeVito, M., Schipul, S. E., Bulluck, J. C., Belger, A., & Baranek, G. T. (2016). Eye tracking reveals impaired attentional disengagement associated with sensory response patterns in children with autism. Journal of autism and developmental disorders, 46(4), 1319-1333.

[15] Alvares, G. A., Chen, N. T., Notebaert, L., Granich, J., Mitchell, C., & Whitehouse, A. J. (2019). Brief social attention bias modification for children with autism spectrum disorder. Autism Research, 12(3), 527-535.

[16] G., Bölte, S., & Falck-Ytter, T. (2016). Altered gaze following during live interaction in infants at risk for autism: an eye tracking study. Molecular autism, 7(1), 12.

[17] Bataineh, E., Almourad, M. B., Marir, F., & Stocker, J. (2018, November). Visual attention toward Socially Rich context information for Autism Spectrum Disorder (ASD) and Normal Developing Children: An Eye Tracking Study. In Proceedings of the 16th International Conference on Advances in Mobile Computing and Multimedia (pp. 61-65). ACM.

[18] KB, P. R., & Lahiri, U. (2016, January). Design of eyegaze-sensitive virtual reality based social communication platform for individuals with autism. In 2016 7th International Conference on Intelligent Systems, Modelling and Simulation (ISMS) (pp. 301-306). IEEE.

[19] Frazier, T. W., Klingemier, E. W., Parikh, S., Speer, L., Strauss, M. S., Eng, C., ... & Youngstrom, E. A. (2018). Development and Validation of Objective and Quantitative Eye Tracking− Based Measures of Autism Risk and Symptom Levels. Journal of the American Academy of Child & Adolescent Psychiatry, 57(11), 858-866.

[20] Wagner, J. B., Hirsch, S. B., Vogel-Farley, V. K., Redcay, E., & Nelson, C. A. (2013). Eye-tracking, autonomic, and electrophysiological correlates of emotional face processing in adolescents with autism spectrum disorder. Journal of autism and developmental disorders, 43(1), 188-199.

[21] Ahtola, E., Stjerna, S., Stevenson, N., & Vanhatalo, S. (2017). Use of eye tracking improves the detection of evoked responses to complex visual stimuli during EEG in infants. Clinical neurophysiology practice, 2, 81-90.

[22] Wei, W., Liu, Z., Huang, L., Nebout, A., & Le Meur, O. (2019, July). Saliency prediction via multi-level features and deep supervision for children with autism spectrum disorder. In 2019 IEEE International Conference on Multimedia & Expo Workshops (ICMEW) (pp. 621-624). IEEE.

[23] Jiang, M., & Zhao, Q. (2017). Learning visual attention to identify people with autism spectrum disorder. In Proceedings of the IEEE International Conference on Computer Vision (pp. 3267-3276).

[24] Duan, H., Zhai, G., Min, X., Fang, Y., Che, Z., Yang, X., ... & Liu, N. (2018, October). Learning to Predict where the Children with Asd Look. In 2018 25th IEEE International Conference on Image Processing (ICIP) (pp. 704-708). IEEE.

[25] Tao, Y., & Shyu, M. L. (2019, July). SP-ASDNet: CNN-LSTM Based ASD Classification Model using Observer ScanPaths. In 2019 IEEE International Conference on Multimedia & Expo Workshops (ICMEW) (pp. 641-646). IEEE

[26] Jiang, M., Francis, S. M., Srishyla, D., Conelea, C., Zhao, Q., & Jacob, S. Classifying Individuals with ASD Through Facial Emotion Recognition and Eye-Tracking.

[27] Dalrymple, K. A., Jiang, M., Zhao, Q., & Elison, J. T. (2019). Machine learning accurately classifies age of toddlers based on eye tracking. Scientific reports, 9(1), 6255.

[28] Król, M. E., & Król, M. (2019). A novel machine learning analysis of eye-tracking data reveals suboptimal visual information extraction from facial stimuli in individuals with autism. Neuropsychologia, 129, 397-406.

[29] Elyazidi, S., Escamilla-Ambrosio, P. J., Gallegos-Garcia, G., & Rodríguez-Mota, A. (2018). Accelerometer Based Body Area Network Sensor Authentication. In Smart Technology (pp. 151-164). Springer, Cham.

[30] Alwakeel, S. S., Alhalabi, B., Aggoune, H., & Alwakeel, M. (2015, December). A machine learning based WSN system for autism activity recognition. In 2015 IEEE 14th International Conference on Machine Learning and Applications (ICMLA) (pp. 771-776). IEEE.

[31] Min, C. H. (2017, July). Automatic detection and labeling of self-stimulatory behavioral patterns in children with Autism Spectrum Disorder. In 2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 279-282). IEEE.

[32] Rad, N. M., Kia, S. M., Zarbo, C., van Laarhoven, T., Jurman, G., Venuti, P., ... & Furlanello, C. (2018). Deep learning for automatic stereotypical motor movement detection using wearable sensors in autism spectrum disorders. Signal Processing, 144, 180-191.

[33] Coronato, A., De Pietro, G., & Paragliola, G. (2014). A situation-aware system for the detection of motion disorders of patients with autism spectrum disorders. Expert Systems with Applications, 41(17), 7868-7877.

[34] Gilchrist, K. H., Hegarty-Craver, M., Christian, R. B., Grego, S., Kies, A. C., & Wheeler, A. C. (2018). Automated detection of repetitive motor behaviors as an outcome measurement in intellectual and developmental disabilities. Journal of autism and developmental disorders, 48(5), 1458-1466.

[35] Rodrigues, J. L., Gonçalves, N., Costa, S., & Soares, F. (2013). Stereotyped movement recognition in children with ASD. Sensors and Actuators A: Physical, 202, 162-169.

[36] Gong, Y., Yatawatte, H., Poellabauer, C., Schneider, S., & Latham, S. (2018, August). Automatic Autism Spectrum Disorder Detection Using Everyday Vocalizations Captured by Smart Devices. In Proceedings of the 2018 ACM International Conference on Bioinformatics, Computational Biology, and Health Informatics (pp. 465-473). ACM.

[37] Rad, N. M., & Furlanello, C. (2016, December). Applying deep learning to stereotypical motor movement detection in autism spectrum disorders. In 2016 IEEE 16th International Conference on Data Mining Workshops (ICDMW) (pp. 1235-1242). IEEE.

[38] Amiri, A., Peltier, N., Goldberg, C., Sun, Y., Nathan, A., Hiremath, S., & Mankodiya, K. (2017, February). WearSense: detecting autism stereotypic behaviors through smartwatches. In Healthcare (Vol. 5, No. 1, p. 11). Multidisciplinary Digital Publishing Institute.

[39] Sarker, H., Tam, A., Foreman, M., Fay, N., Dhuliawala, M., & Das, A. (2018). Detection of Stereotypical Motor Movements in Autism using a Smartwatch-based System. In AMIA Annual Symposium Proceedings (Vol. 2018, p. 952). American Medical Informatics Association.

[40] Airij, A. G., Bakhteri, R., & Khalil-Hani, M. (2016). Smart wearable stress monitoring device for autistic children. Jurnal Teknologi, 78(7-5).

[41] Rihawi, O., Merad, D., & Damoiseaux, J. L. (2017, August). 3D-AD: 3D-autism dataset for repetitive behaviours with kinect sensor. In 2017 14th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) (pp. 1-6). IEEE.

[42] Ward, J. A., Richardson, D., Orgs, G., Hunter, K., & Hamilton, A. (2018, October). Sensing interpersonal synchrony between actors and autistic children in theatre using wrist-worn accelerometers. In Proceedings of the 2018 ACM International Symposium on Wearable Computers (pp. 148-155). ACM.

[43] Goodwin, M. S., Haghighi, M., Tang, Q., Akcakaya, M., Erdogmus, D., & Intille, S. (2014, September). Moving towards a real-time system for automatically recognizing stereotypical motor movements in individuals on the autism spectrum using wireless accelerometry. In Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (pp. 861-872). ACM.

[44] Großekathöfer, U., Manyakov, N. V., Mihajlović, V., Pandina, G., Skalkin, A., Ness, S., ... & Goodwin, M. S. (2017). Automated detection of stereotypical motor movements in autism spectrum disorder using recurrence quantification analysis. Frontiers in neuroinformatics, 11, 9.

[45] Lanini, M., Bondioli, M., Narzisi, A., Pelagatti, S., & Chessa, S. (2018, June). Sensorized toys to identify the early 'red flags' of autistic spectrum disorders in preschoolers. In International Symposium on Ambient Intelligence (pp. 190-198). Springer, Cham.

[46] Moradi, H., Amiri, S. E., Ghanavi, R., Aarabi, B. N., & Pouretemad, H. R. (2017, November). Autism Screening Using an Intelligent Toy Car. In International Conference on Ubiquitous Computing and Ambient Intelligence (pp. 817-827). Springer, Cham.

[47] Cabibihan, J. J., Chellali, R., So, C. W. C., Aldosari, M., Connor, O., Alhaddad, A. Y., & Javed, H. (2018, November). Social robots and wearable sensors for mitigating meltdowns in autism-A pilot test. In International Conference on Social Robotics (pp. 103-114). Springer, Cham.

[48] Heathers, J. A., Gilchrist, K. H., Hegarty-Craver, M., Grego, S., & Goodwin, M. S. (2019). An analysis of stereotypical motor movements and cardiovascular coupling in individuals on the autism spectrum. Biological psychology, 142, 90-99.

[49] Alam, M. E., Kaiser, M. S., Hossain, M. S., & Andersson, K. (2018, September). An IoT-Belief Rule Base Smart System to Assess Autism. In 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT) (pp. 672-676). IEEE.

[50] Rodriguez, J., & Del-Valle-Soto, C. (2018, November). Predictive Tool for Planning the Scaling and Interference of Wireless Sensor Networks. In 2018 IEEE 10th Latin-American Conference on Communications (LATINCOM) (pp. 1-6). IEEE.

[51] Mohammadian Rad, N., van Laarhoven, T., Furlanello, C., & Marchiori, E. (2018). Novelty Detection using Deep Normative Modeling for IMU-Based Abnormal Movement Monitoring in Parkinson's Disease and Autism Spectrum Disorders. Sensors, 18(10), 3533.

[52] Saini, R., Kumar, P., Kaur, B., Roy, P. P., Dogra, D. P., & Santosh, K. C. (2019). Kinect sensor-based interaction monitoring system using the BLSTM neural network in healthcare. International Journal of Machine Learning and Cybernetics, 10(9), 2529-2540.

[53] Ahmed, I. U., Hassan, N., & Rashid, H. (2017, September). Solar powered smart wearable health monitoring and tracking device based on GPS and GSM technology for children with autism. In 2017 4th International Conference on Advances in Electrical Engineering (ICAEE) (pp. 111-116). IEEE.