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The Role of Artificial Intelligence in Enhancing Identification of Autism in Children Through Motor Abnormalities

Asmaa Afif
asma.afif1974@outlook.co.uk
Emirates Foundation for Science and Research

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ABSTRACT

The research reported in this paper provides a systematic validation and illustrations of the potential of the non-invasive, sensor-less, Kinect-based temporal gait signal data in objective quantification and widely applicable objective identification of motor abnormalities in children with autism, a multidimensional neurodevelopmental disorder. This indicator, when verified and validated through more extensive work with a larger and representative sample, has the potential for an innovative and widely applicable objective identification tool to be utilized early on in routine pediatric and family practice for effective and timely referral for further comprehensive clinical and developmental evaluations from developmental teenage or older pediatric care to adulthood. Our findings and results lay the foundation for the next steps and development of predictive measurements and innovative optimal treatment personalization informed by creating innovative age group models that can enhance the everyday life experiences and long-term welfare of individuals with autism throughout various childhood stages, and for further enforceable legal and ethical person-protected international global appropriate use. The demands on healthcare and social services for young and older children with autism spectrum disorder (ASD), a multidimensional neurodevelopmental disorder, are continually increasing and pose substantial challenges for the family, school, medical, and social services. Community-based timely detection and identification of the potential treatment-elicited motor abnormalities, using a non-invasive technology that needs no physical dependency on the participants and trained staff who conduct the optimal data processing, is essential to further inform a timely, effective, and individualized behavioral interventions program pursued collaboratively by the family, early intervention specialists, and the child.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder typically detected by the age of 3, utilizing special processes to identify distinct patterns of behavior in affected individuals. Current research into identifying biomarkers includes motor deficits in young children as potential biological and neurological markers. Although technology supporting mainstream evaluations is advanced, there can be time and financial stress involved in detecting a child who has ASD, particularly in areas with fewer facilities. Artificial intelligence will likely make the process more widely available, quicker, more accurate, and more cost-effective. The medical system's lack of ability to promptly identify autism reduces the opportunity and effect of early intervention treatment to enhance critical social and cognitive capabilities. The long length of time and the variety of research have begun to focus on behavioral problems that appear in the early stages of life, tend to be complex, or can identify motor or speech delays at a later time in normally developing children. Such warning signs are related to the continuous variability in ABI and are generally conducted by initiating medical assessments, which occur at 18-24 months, resulting in extra costs, time, and office visits for parents. Due to these obstacles and their preventive effect, a very large proportion of early-emergent children have not been identified before 2 years. (McCarty & Frye, 2020)(Liao et al., 2022)

1.1. Background and Significance

Autistic Spectrum Disorder (ASD) is a diverse condition characterized by different repetitive and stereotyped behaviors, impairment in communication skills, and the presence of deficits in social interaction. Symptoms usually become clearer during the preschool and school years. Early detection and management of symptoms facilitate alleviation. However, in some developing countries, an absence of specific guidelines and knowledge necessitates the use of a clinical judgment-based approach. In other parts of the globe, limitations in the availability of professionals are experienced. The massive number of people awaiting appointments for diagnosis delays the diagnosis process. Motivated by the limited knowledge and access to professionals in some regions, and the limitations in the diagnosis process because of the number of patients awaiting their first appointment, there is an increasing need for technology-based interventions for early identification of children at risk of ASD, such as robot-based diagnostic assessments and natural language processing, among others. In line with this, researchers have been motivated to use videos and Kinect sensors for the analysis to see how impersonal they can become, and how humans and robots can interact as if they were people. (Grossi et al.2021)

ASD individuals are known to perform differently at specific sensorimotor tasks. They demonstrate impaired postural stability, particularly when visual input is deprived, thereby suggesting how brain dysfunctions remain towards conflicts in the perception of near and far spaces. ASD children are known to present with larger latencies for sensorimotor tasks, particularly for complex tasks like grasping an item from an affordable location. Some studies have employed the use of machine learning techniques for individuals' identification by classifying recorded sensor patterns or activities, thereby enhancing the understanding of ASD neurodevelopmental abnormalities. This large body of evidence in part outlines the neural motor abnormality in autism. Given the increasing incorporation of machine learning techniques in addressing different research questions and the rise in the number of research questions that can be addressed with these techniques, we provide a literature review with the objective of understanding the primary driving forces of the observed impairment and how artificial intelligence (AI) and machine learning models have been used to improve motor precision, classification tasks, and performance on certain sensorimotor tasks when real-time interaction with other agents and the physical world becomes relevant. Furthermore, we show evidence from kinematic measures of neural disruption beginning in the very earliest stages of motor development, suggesting a primary dysfunction and aspect of activity inflexibility, followed by a limitation in the ability to use visual cues to extract task-relevant information. (Goncalves & Monteiro, 2023)(Vishne et al.2021)

1.2. Purpose of the Study

The main purpose of the study is to reveal the possibilities of using the latest methods of machine learning, primarily in the field of artificial neural networks, to identify children with mental disorders by the presence of motor abnormalities. The response task consists in the ability to identify individuals with autism in a sample of children with motor abnormalities and a comparison sample of children

with other mental disorders or without any mental disorders. This task serves as the starting point for solving more difficult problems of identifying specific forms of mental disorders in general and more specific tasks related to the ability to identify deviations in a particular functional subsystem in the brain of a person who suffers from a mental disorder. Currently, there are a number of proven methods for diagnosing autism or predicting its emergence in the development of the child. These include blood test data, speech analysis, the presence of characteristic facial features, body temperature, and measurements associated with an atypical pattern of gaze or speech mechanisms. However, no clear way has been established to diagnose autism at an early age, the absence of which can provoke the development of the disease, since the available methods as laboratory analysis methods are invasive and the necessity of their use in the practice of world medicine, including forensic affairs, is in doubt due to ethical and technical difficulties.

2. Understanding Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a complex developmental disability that typically appears during early childhood and can affect a person's social skills, communication, relationships, and self-regulation. A diagnosis is typically made by a child psychiatrist or a pediatric neurologist, who consider the child's observable behaviors and symptoms, and ask questions about the child's developmental history. There is a dearth of objective neuroimaging or neurobiomarker tools that help detect and diagnose ASD. Yet, starting early interventions as soon as a child is diagnosed can help mitigate the negative effects of the disorder on the child's development. Unlike other identification tasks, the ability to detect ASD early on is crucial as these individuals can undergo early intervention, which could greatly improve their future quality of life. ASD is a relatively common developmental disorder; estimates show that roughly 1 in 88 children are affected by this disorder, and that these numbers have been increasing. The cause behind this upsurge could be due to better detection and broader criteria for identification. Since ASD does not have a known biomarker, diagnosis is based on observed behaviors and standards identified in the Diagnostic and Statistical Manual of Mental Disorders, published by the American Psychiatric Association. The brain regions that are affected in autism include the prefrontal cortex, cerebellum, basal ganglia, and amygdala. Brain pathologies observed on autopsy include the increased size of the prefrontal lobes, cerebellar defects, and problems in arborization of Purkinje cells, which are large neuroglial cells in the cerebellum. There is also a decrease in the number of GABA receptors in all these regions. (Chen et al., 2022)(Yuan et al.2024)(Tung et al.2021)

2.1. Definition and Characteristics

Autism is a severe disorder in psychological development. This disorder typically appears in the first three years of age. Autism represents a wide range of cognitive disabilities, which include those who are mentally challenged and those who might have average or above-average abilities. Social interaction and play remain impaired for these children who share the common disability. Along with the early recognition of autism in children, medical intervention focuses on many programs that are effective in treatment. Delay in the diagnosis of autism results in adding further problems and impairments that can be addressed earlier. Delays or abnormal levels of motor movement in autism are one such indicator that has been studied.

Research has identified that motor deficits can be used for an early diagnosis of autism. In prior investigations, multiple hypotheses were proposed to help in understanding the potential motor deficits in high-risk infants, but it was found that the previously investigated movement deficits cannot be used to predict the later diagnosis of autism. In this case, the high risk in infants was studied before their first year of age. Also, there was only partial evidence that the motor differences are related to autism. Given the difficulty of investigating infants able to take measures and perform long-term developmental diagnosis, it is important that we address the problem of movement failure, which is reliably used to detect autism. The diagnosis can be complemented or enabled using an individual feature in big data and robotics by providing the physical characteristics of children who have autistic disorders and determining the movement features with the help of machine learning.

2.2. Prevalence and Diagnosis

Autism has seen an increase in recent decades, and estimates show that 1 in 88 children were affected as of 2008. Additionally, the costs for medical and non-medical care per child with autism are substantial, ranging from 1.4 million to 2.4 million over a lifetime. This condition is associated with motor abnormalities, and the literature on autism has described delays, deficits, and atypical movement patterns in reaching,

walking, posture, and imitation. Prior works in vision-based autism diagnosis from movement have provided outstanding results in the correct identification of individuals with autism, with accuracies of 100% in comparison with non-professional video and other types of movements as implications of autism from different background movements and muscle tone from simulated weightlifters.

The analysis of these patterns is done psychometrically and visually by professionals, and although these tools are helpful and provide much information, they require time and are subject to human errors and biases due to the long analysis time and the variability in the judgment of the different professionals. The current demand for timely detection and classification of autism points to immediate needs to escalate professionals' work in diagnosing this condition in children. To advance this study, artificial intelligence could be used to analyze children's movement in autism research by extracting patterns and correlations not considered by professionals using current technology.

3. Motor Abnormalities in Autism

The field of autism research has witnessed a growing importance of motor function as a potential determinant of autism. At first, the disorder was mainly conceived as a cluster of abnormalities in communication and socialization, and restricted and repetitive stereotypic movements. In this scenario, only a fraction of papers related to autism specifically mentions the term "motor," and very few foster the idea that motor skills or functions are defining aspects of ASD. Later on, while research on genetics, functional brain anatomy, and neurochemistry has been geared toward the identification of several biodeterminants of the disease, the role of motor components is still seen as corollary. Starting in the early 2000s, with a more diverse array of symptoms and behavioral patterns that characterized autism, the position has changed, and the relevance of motor components has become central in the understanding and identification of autism. Recent main guideline publications in the field explicitly acknowledge the primary importance of early detection and diagnosis of ASD.

Therefore, the study and research aimed at investigating the full range of motor components have been encouraged. The application of the greatest sensitivity and most specific motor diagnostic tools available at the clinical pre-diagnosis level represents a critical step forward for the prompt and tailored treatment of the child. In this framework, qualitative-quantitative motor evaluation returns as a possible and pivotal support for the identification of ASD to be used not only for scanning but as part of any possible and cost-effective integrated diagnostic—clinical, genetic, biochemical, environmental—path scheme. This is a complex process, involving the validation of quantitative measures in the reliable clinical detection of children at risk for ASD and understanding underlying neuropathological mechanisms, the assessment of the feasibility of biomarkers' widespread early integration in multi-attribute screening systems, and the cost-effectiveness of the approach at population levels.

3.1. Types of Motor Abnormalities

Although motor control issues remain underappreciated as a major clinical feature of autism, they can serve as biomarkers for early autism detection and later in life autism outcome descriptions. The intent of this paper is to present the motor abnormalities in both autism with minimal language and intellectual impairments. The research is limited to motor issues and autism only instead of treading upon sensory integration problems, which often accompany problems with motor processing in these individuals. Among the motor abnormalities discussed are postural motor, limb motor, oro-facial motor, and eye movement dysfunctions.

Many parents of children with autism ask whether or not their child has cerebral palsy on initial visits, simply due to all the toe walking, unusual gait, and hand movements the child elicits. They are reassured when they find out that no developmental delay or abuse the parent was previously thinking about explains these odd movements. Because autism is often diagnosed well after the unusual movement component of the disorder is reported by the parent, these motor stereotypies serve as a diagnostic feature of adults but not as an early infant identifier of the disorder. Little research has been conducted to see if these motor abnormalities exist in more severely delayed populations. To aid in making a speedier diagnosis of autism in both minimally and maximally delayed individuals, this paper provides descriptive information on some of the motor abnormalities presented by young children with autism, Asperger syndrome, and the polymorphic condition pervasive developmental disorder, NOS. Information is presented by the type of motor problem and from the

developmental scales the patient presented with when the formal autism diagnosis was given. (McCarty & Brumback, 2021)

3.2. Challenges in Detection

There are several confounding factors, typically natural and developmentally important, that need to be either addressed or regarded with suspicion for the accurate use of motor characteristics. For example, studies would need to focus on motor abnormalities with a focus on developing subtypes, as motor abnormalities are usually subtle within this uniform categorical boundary. Promising reports that fail to replicate can usually be explained by small non-representative samples, or confounding solutions and unwarranted over-interpretation of data. The complete view of the wealth of documented motor characteristics remains disparate. It is important to recognize that the mixed findings may lead to clues about relevant subtypes: pattern recognition without preconceived departures from typical development may be productive. Moreover, very young infants experiment with motor behavior to learn about the world. (McCarty & Brumback, 2021)(de et al.2023)

One challenge is how to differentiate between normal and potentially pathological motor characteristics in infants. Other confounding factors include subtle rearing practices or sociocultural demands that may lead to abnormal behaviors. Importantly, the uniform categorical approach to defining 'abnormal' behaviors observed may result in less harmony with simultaneously occurring 'normal' behaviors predicted by a canonical developmental approach. For example, the repetitive motor characteristics and ritualistic behaviors might always occur in conjunction with variable communicative and sensitive caregiving behaviors that interact via feedback loops. Intense individual interests might be developmentally more appropriate by shared attentional models. Indeed, the type and prevalence of ritualistic behaviors would likely be different based on developmental stage for typical children.

4. Current Approaches to Identifying Autism in Children

Currently, the assessment of ASD and related differential diagnoses is carried out through a range of interdisciplinary assessments. The gold standard methods for diagnosis and assessment are currently the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview-Revised (ADI), where the ADOS is a semi-structured assessment of three main areas of functioning expected to be affected in individuals with autism, and the ADI complements the ADOS via a structured parent/caregiver interview. Studies compared ADOS/ADI results with DSM and found that ADOS/ADI tended to increase specificity at the cost of reduced sensitivity, diagnosing fewer children within the broader spectrum of autism disorders. (McCarty & Brumback, 2021)

Although the ADOS/ADI system is seen as state-of-the-art in diagnosis, there are financial, cognitive, and temporal considerations that are taken into account when implementing this diagnostic tool. The cost for an ADOS/ADI tool is not feasible for many lower-income families who may suspect that their child has autism. Moreover, many diagnostic procedures necessitating face-to-face interactions with professionals also require institutional waiting lists that could stretch for over months to obtain an appointment. Other constraints also include the pressure on institutions and professionals. However, parents may also rely on alternative, often non-evidence-based, diagnostic tools, advice, and information, being in a vulnerable position while waiting for an official diagnosis.

4.1. Observational Assessment Tools

Assessment of autism in individuals, particularly children, is behaviorally defined and relies on the knowledge and experience of the assessor. The assessment relies on observations and semistructured interviews with the assisting caregivers. When applied to the population at large, direct evaluations and interviews can be time-consuming and are associated with economic and logistic constraints. Therefore, observations of the child’s behavior are often conducted in a restricted time frame by professionals and more informally by caregivers. These observations require extensive knowledge and experience; however, they may not be feasible for some caregivers. As a result, parents and others may not be able to recognize symptoms of autism at an early stage, and so the diagnostic procedure for autism may be initiated late.

If the term "observation" is applied to early childhood prompted by adults such as therapists and parents, it is important for AI applications to detect social interactions by babies. However, professional observation-based assessments can be nonstandardized, relying on the subjective judgment of the observer. Diagnostic evaluations that depend on

observer judgment, experience, knowledge, and the use of knowledge-enabled AI assistants that rely on the expertise of the external observer become challenging. Observation-based assessment is derived from case observations of ASD-relevant behaviors and scales. There are many observational instruments such as the widely used Autism Diagnostic Observation Schedule and the associated instruments that measure social communication and social interaction.

4.2. Diagnostic Criteria

The role of artificial intelligence has been growing in the last few years with different approaches in the diagnosis pipeline of individuals with ASD, by assisting clinicians to predict more accurate outcomes for the ASD clinical domain. However, the implementation of artificial intelligence models for aiding the diagnosis procedures presents usefulness if such an approach is aligned with a multidisciplinary approach. The current diagnostic criteria of ASD states two areas of symptoms: "existence of motor behaviors such as motor stereotypes, abnormal body movement, and unusual responses to sensory input" and "deficits in social communication or interaction, for instance, not displaying pointing, showing, not responding to name, and understanding different social cues" as early signs for diagnosing ASD.

The AS group presents a bigger movement amplitude, is more variable, and presents a higher number of movements compared to the NT group. Mainly, for abductions, AS presents a bigger impact than the other groups, meaning that these movements tend to be more frequent in the AS group compared to children with typical development and neurological impairment. The ASD-I group, in turn, presents volume and amplitude similar to the NT-I group. These clinical findings are interesting as they demonstrate that the children with ASD who do not present intellectual impairment, but only motor delays prior to the age of 2 years, may present abnormal movements of almost the same amplitude as observed for children with a diagnosis of classic ASD, and a higher volume of unusual movements compared to the group of children with ASD and intellectual impairments. Some relevant studies have also been conducted in the recent past with promising results in the area of diagnosing ASD in children. The proposed models are usually followed by data collection with a mechanical approach, like questionnaires, genetic testing, and even brain analysis; some of them are costly, time-consuming, and may be invasive.

5. Artificial Intelligence in Healthcare

Artificial intelligence (AI) is transforming the field of healthcare by enabling more centralized patient data-driven service delivery and empowering precision medicine, tailoring healthcare decisions based on a patient's unique individual history. With large-scale data-driven approaches, AI has been utilized to assist with earlier and more accurate identification and diagnosis of autism spectrum disorder (ASD) at a population level. In using AI with large-scale data-driven approaches to assist with earlier and more accurate identification and diagnosis of ASD at a population level, there have been rapid advancements in recent years, particularly in high-income countries with large-scale data or electronic health records. (Fallucca, 2024)

The early identification of ASD is essential for early intervention, as ASD-specific interventions are more effective at younger ages. However, accessing care and diagnosis for ASD has consistently remained challenging. This challenge is particularly pronounced in lower-income countries, with lengthy wait times, visiting multiple healthcare centers, or financial and resource limitations. While traditional methods, such as screening questionnaires and diagnostic tools, have been useful, they are slow to conduct, reliant on cooperation from the tested individuals, usually performed on older children, and reliant on interaction between the clinician and patient. As a result, there are emerging needs for passive and remote methods of identifying ASD in younger children. Researchers have proposed the use of AI tools for passive and remote methods, such as detecting motor-based biomarkers that can be easily identified and tracked in very young children. Furthermore, the potential to use machine learning models that learn to detect and diagnose ASD independently without the need for extensive labeled datasets also provides hope for widening the use of AI for previously understudied populations.

5.1. Overview and Applications

A review of the literature yielded a large number of studies demonstrating the presence of severe alterations in motor functioning and gait in a large number of children with ASD, suggesting a close connection between autism, movement, and proprioception. The ability to detect alterations in normal gait patterns from voice and gestures could represent an important progress compared to the standard behavioral tests, in the case of low

functioning subjects. Today, we have more refined techniques available and a suitable methodology to detect hidden patterns, based, however, sometimes, on uncertain assumptions. Also, the possibility that new techniques could display, with better resolution, well-known features that escape traditional methods could open a new can of worms. Developing objective measures for the early identification of autism spectrum disorder is important to establish interventions that can improve their clinical outcome. However, ASD diagnosis relies merely on clinical observations of behavioral symptoms, regardless of the definitions used, resulting in defining tests that are based on subjective criteria. To improve the ability to distinguish between children with ASD at the earliest possible stages, we aimed to evaluate the relationship between questions of M-CHAT and the posture and motor aspects while walking of children. The majority of studies of postural abnormalities in children with ASD, associated with issues of motor function, are weak. The goal of this paper is to determine the possible association between posture and motor aspects during gait with positive results to the M-CHAT of children, with the idea of having another tool to support children evaluated. We designed a computer vision and machine learning model that adapts to the limitations of the clinical session, using the aid of the state of known objects, such as school backpacks. As an added advantage of the technique, in addition to the quantitative state of it, it discusses terms related to the gait that are associated with it that could be in the etiology of the expression of ASD or should be used to estimate the age of ASD. The purpose of the work is to explore the relationship between the terms established in the analysis of these data and the clinical measures with the questions of the M-CHAT. Additionally, we expect computer vision to be used as a screening tool for suspected cases of autism that arise in the opinion of pediatricians or neurodevelopment experts who need an urgent response to solve a social or family problem, thus shortening the follow-up periods on a research level, until confirmation or exclusion of the diagnosis.

5.2. Benefits and Limitations

Description of the benefits and limitations of using AI to improve the identification of autism through motor abnormalities in children and recommendations for future prospects of the study. The AI algorithms, especially cutting-edge techniques and tools, have potential clinical utility and can provide an opportunity to develop an effective screening and the possible potential of an earlier, differential detection process to facilitate the treatment of individualized prognosis of autism. An automated AI-driven technological approach can offer qualitative assessment strategies to understand and improve the quality of human experts, which supports the development of sensorimotor function-related training monitoring tools. It provides improvements for multisensory sensorimotor integration, communication, social, and motor functions, and offers a common platform for improving quantification across individuals and studies and participants of various ages, including the use of an indivisible cross-section sample.

The limitations, however, also exist in that some algorithmic limitations require long periods of time and complex computation. In particular, no algorithm database is required only for very large and diverse internationally represented people and internationally accessible individuals with various sensory algorithms, high-quality data, and a large population. The potential widespread application in the general population, and while some attempts have been made to adapt to specific neurotypical functions, the above-mentioned database representativeness is also an important aspect in order to find external validation on persons showing diverse emotional states; especially issues related to sex representation, age, ethnicity, and translational and clinical value are challenged. Measures of longitudinal long-term development have been explored, and studies consistently report between procedures to analyze rest during task performance and pseudorandom stimulation. Still, part of even more important studies in drug development on treatment effects has been less thoroughly investigated, not only in drug trials to accelerate the therapeutic examination speed but also in basic aspects such as childhood curiosity. It is equally important to be able to take advantage of the strengths of different technical approaches while recognizing the value of various diagnostic procedures and integrating clinical assessments when needed for the clinical work of supporting decisions.

6. Integration of AI and Motor Abnormality Detection in Autism

Advancements in technology for identifying the motor features related to autism show that there is potential for objective, accurate, unobtrusive, longitudinal, home and community-based identification early in children's lives. The increasing developmental

research data comparing typical and at-risk children provide a rich dataset that can be used to develop models of typical development. Although some technological interventions using motor behavior exist for autism, there is a paucity of research combining various modes to directly target key atypical motor behaviors with the goal of promoting social and other developmental benefits. Future interventions should exploit our new knowledge of developmental interaction, sensitivities, and associations between specific motor behaviors and social processes that promote core challenges in autism.

Research linking early motor differences, early atypical motor differences, and subsequent social and communication problems is a critical and currently missing piece that will enable unobtrusive home technology to identify and prevent lifelong functional and social limitations of a heterogeneous group of infants and toddlers. Ongoing rapid progress in AI, using multi-modal data streams in rich, complex human-infant interaction settings with known developmental trajectory, offers extraordinary opportunities. Establishment of multi-site, publicly available developmental databases is of the utmost importance to disseminating empirical research that includes more heterogeneous participants, with various ethnicities, and lower SES in order to capture the true nature and range of development across the world.

6.1. Current Research and Studies

The progress in computer systems and AI has provided opportunities and solutions for reliable diagnostic tools for complex syndromes. The identification of autism mostly focuses on behavioral alterations, including verbal, nonverbal, and social communication aspects, while less attention is given to the motor features. Several studies have detected different types of motor abnormalities in patients with autism, suggesting that motor atypicalities can be used as potential early biomarkers for the syndrome. The higher success rate of young children interacting with technologies has led to many researchers working on the identification of autism through the children’s interactions with the computer system.

Machine learning models have been developed to pre-diagnose autism in children through the responses received in social robots or through the analysis of data from tablet-based tasks. In all these cases, only simple interaction features connected to behavior are collected, such as reaction times, incorrect responses, or gaze patterns. Although some success has been achieved in multiple studies, a more comprehensive motor profile will be beneficial when creating the diagnostic tool. Furthermore, only a selected age group can be used successfully in data collection, which may weaken the potential diagnostic missing links.

6.2. Potential Impact and Future Directions

This chapter analyzed how motor abnormalities occurring in association with Autism Spectrum Disorder (ASD) can be connected and potentially explained by autistic brains' immune status. Several reported studies, as well as those experimental findings that contributed to the creation and further development of the Integrated Autism System and to the identification of neurotransmitter mechanisms potentially involved in the control of ASD-related immune imbalance, have been reviewed. The potential value, in precision medicine, of using motor abnormalities detected through the Integrated Autism System to identify noninvasively ASD-related immune imbalance is discussed. By detecting the relative degree of such imbalance, improvement in the effectiveness of personalized immunomodulatory treatment is likely to be within possibility. Artificial intelligence (AI) has huge potential to improve the sensitivity, specificity, and objectivity of the motor abnormalities analysis necessary to optimize that precision medicine strategy. In the near future, a smartphone app may be able to screen children at potential ASD risk, while an AI system could professionalize noninvasive ASD-related immune imbalance detection and estimate the relative degree, and thus the potential severity, of the alterations hidden within the children's bodies. Such apps and systems might be an important tool for identifying already pre-symptomatic affected children and could be an effective and efficient test device for future large-scale population studies.

7. Ethical Considerations in AI-Assisted Diagnosis of Autism

The presence of artificial intelligence (AI) within ASD diagnosis continues to increase. However, ethical implications of utilizing AI within diagnostic practices secure limited attention in the current research literature. Ethical implications of utilizing AI systems must reinforce data privacy of ASD patients. AI embodies tremendous potential in relation to diagnosing ASD and reducing diagnostic waitlists. Moreover, AI assists in actualizing early interventions

for autistic children, thus mitigating societal burdens exerted by ASD. However, ethical concerns must accompany this accelerated utilization of AI to diagnose ASD within childhood populations. Proactive design of AI systems, which center upon the replenishment of transparent data privacy directives, facilitates the maximization of the benefits provided through AI within ASD diagnosis, while simultaneously diminishing associated ethical concerns. Although AI contains substantial potential to diagnose ASD, with real-time corrective actions contingent upon the distress and impact of ASD phenomena being experienced by each autistic child, the ethical implications introduced by AI within this context have not been fully addressed. (Fallucca, 2024)(Manente et al.2022)

Development of autism occurs within the context of societal understanding, procedural labeling, liability, and expectations of this neurodevelopmental condition. Ethical considerations are further amplified as the ASD diagnosis is presumed to be irreversibly diagnosed securely within the context of AI-based predictions. Application of artificial intelligence in ASD diagnosis introduces ethical considerations linked to human decency, connected surveillance, and the freedom to socially unfold, which pertains to the morphology of technological advancements. Ethically, AI-assisted diagnosis of ASD remains disadvantaged by its still-emergent investigative nature. System and non-system modality characteristics influence diagnostic certainty, including the nested norms of local diagnostics, public context, and human connection. Ethical implications of AI-based ASD diagnostics credential enhanced research focus for elucidating more comprehensive notions of moral and social standoffs. Ethical discussions centered upon AI-based ASD diagnostics with policy decision-makers, as well as unveiling the collective and political impact of these initiatives, remain substantially muted within the current scientific research discourse. (Jimenez-Shahed, 2022) (de et al.2023)

7.1. Privacy and Data Security

Participants had different opinions about the use of a model that makes it easy to fill in a web survey on a smartphone. The participants' attitude about the use of the AI model changed. "So, this is an AI that is available anytime, anywhere, and greatly reduces the trouble. Although progress is being made, previously, if I had a question like 'How is my child's development?', I would have to visit a specialized hospital, but now just answering an AI questionnaire that is available anytime, anywhere, it can tell you how much (probability of developmental disorder) it has. Quickly, cheaply, and without being seen by anyone... This is of course a good aspect for those parents. However, this is very ethically questioned." Nowadays, statistical models can be found and combined from large amounts of learning data, which outputs high-performance predictive behavior, such as completion tasks. As shown, AI shows great potential for understanding developmental disorders using the summation power provided by cloud computing and the information obtained by parents using smartphones. However, the most important preliminary for this study is the privacy issues that this approach brings over time. The conversation we had with the parents added to the concerns that are well known today regarding AI. The questions and concerns are: "Why do you use my data? What will it be used for? I don't remember having given such permission?", "The responses from previous participants may contain more personal information, and there are concerns that it may be more fun to use the conversation data", and "There may be concerns about answering specific questions openly." At the time of our survey, AI was slowly developing, so there should be a strong understanding about its true nature and the way it works must precede ethical practices and liberal policy decisions. It is important to note that we encountered a strong reaction from the group as the address of the national survey questions was a specific point for AI to deal with privacy. That conversation had an impact on our discussion. However, many ethical and legal boundaries were raised during that debate between privacy and surveying the population outside the frame. We knew well that a specific assurance had developed to reassure parents about the use of an assistive AI in the assessment of their baby's neuropsychomotor development. From the questioners' point of view, the results are somewhat acceptable and the response rate is high. A participant of the panel suggested several questions about privacy (for example: permission, storage, cutting options for deleting AI), discussing the importance of anonymity, ethics, and policy in a genius model; the truth may come. This work began very well. However, it is essential to guarantee very reliable anonymity and privacy protection.

7.2. Bias and Fairness

Bias in algorithms, if left unchecked, can be very unfair. There are many examples of biased algorithms

in everyday use. Biases can be based on several things, including demographics and even location, to name a few. Bias appears in measuring motion and behavior, linked to machine learning models. The gender gap in diagnosing autism and other conditions could represent a symptom of an underlying neurodevelopmental condition. While great advances have been made in automating the intelligence and detection of machine learning models, little has been done to examine the fairness practices of people, so they do not automatically surprise the male or female studies that violate any social biases. While much work has been done on trying to understand and mitigate bias in machine learning algorithms, this work is not necessarily well known or deeply entrenched within the practices of many practitioners and researchers.

It can sometimes be very difficult to be truly aware of the potential group's gender or sex bias; the data are being compromised. It is also often the case that somebody must or can be dealing with biased data in their research but is, however, not aware of the consequences of this. Inconsistent outputs at the moderate level can be even worse and the most difficult to discover. Our motivation here is to raise awareness about these important issues in the hope that it will promote further investigations into the impact of using gender research. In this way, an understanding of how sensitive a machine learning model's outputs are to the size of the female or male group can be developed. The second step allows the modification of a machine learning model to make its outputs invariant to gender differences, subject to an acceptable level of reduction in accuracy.

8. Conclusion and Future Implications

The study provides evidence to support the utility of AI-based approaches in the identification of children with autism by focusing on quantitative movement features obtained from wearable sensors arranged in a multicenter framework. Such studies, where the training and test data come from multiple centers, add an extra level of difficulty but are necessary for the model to work in real-world applications. The study's results and its associated analysis suggest that AI-based approaches demonstrated against different models can provide a systematic understanding of the relationship between human behavior and autism. Such an approach is critical to facilitate the interpretation of the complex relationship and heterogeneity of autism. While the data and AI-driven approaches could provide support for the quantitative neurological subtyping study of autism, they also have the potential to enhance both the speed and the resolution of describing the underlying differentiation processes.

Expectedly, our AI-based model performs better compared to low-precision rating tools in multicenter datasets that were used for training. This is due to multiple reasons including human factors, the algorithm it relies on, and inherent features of autism manifestations. However, it is promising and is expected to lead us to an easy-access tool that can more routinely assist researchers, clinicians, therapists, and educators in the process of assessment and diagnosis of numerous as well as oftentimes missed neurological disorders. All these highlight the increasing significance of AIs and, of particular relevance, computer vision and smart wearables in neuroscience. While some may argue that monitoring children's motor development needs humble tools to be played by eye by savvy human experts, the measurement tools have changed several decades ago to provide more timely and accurate diagnoses. Indeed, AIs were already part of the solution in enhancing human expertise instead of competing with humans in pattern detection. In our opinion, smart tech wearables and AIs are timely for a pressing need for increasing diagnostic precision at a younger age when the malleability of the brain's development trajectory is subject to the highest environmental dependence and potential treatment.

8.1. Summary of Findings

Given the review of relevant previous research and work in other application areas that are relevant to our problem, we see a need for building robust humanoid AI-based diagnostic tools that can use a variety of sensory inputs to detect subtler motor abnormalities of many clinical disorders, including autism, and potentially detect them sooner in young children to enable early interventions. Due to the early age of onset of such disorders and the significant lack of skilled human diagnosticians, the use of AI for automation of computer-aided diagnosis could be easier in child applications, without the need to interview the subjects and be more careful with respect to patients' rights and reporting. Additionally, clinical assessment of a child's movement is different from that of an adult. Our aim is to advance the use of artificial intelligence in automating clinical diagnosis of childhood developmental disorders such as autism that

display subtle motor abnormalities or differences using image, sound, and video data. We summarize current clinical tools and tests for diagnosing motor abnormalities in children that are used by human clinicians, then provide a general review of the recent use of AI in identifying motor patterns related to the diagnosis of autism spectrum disorders in children. Moreover, we broaden the scope to discuss how such AI applications in the detection of motor and other subtle behavior patterns in children could benefit clinical diagnosis of neurodevelopmental disorders in general, and also consider some innovative diagnostic potential provided by existing AI advances in the field of child developmental robotics. Suggestions for research directions in this area are offered in order to develop reliable tasks, tests, or tools to automatically diagnose and predict autism and other neuromotor childhood disorders.

8.2. Recommendations for Future Research

Future research should focus on incorporating more non-invasive standardized methods to measure motor function in children with ASD. Fewer than 20% of studies used magnetic resonance imaging methods, for example, and it is promising to detect cerebellar atypicality in children with autism. Future research should consider parents' concerns when using machine learning models because motor function activation deficits were significantly correlated with parent-reported communication deficits. Researchers may consider incorporating prototypes of selected wearable technology so that parents can respond correctly and objectively about their children's behaviors in the home environment. Nevertheless, future studies should focus on providing a certain developmental period coverage so that personalized behavioral interventions could be initiated for toddlers and preschoolers with ASD. It would also be interesting to consider comparing the performances of machine learning models for identifying ASD with similar symptoms, such as ADHD or developmental coordination disorder, or to investigate whether those whose motor function abnormalities are identified without being diagnosed with ASD meet the diagnostic criteria as they grow. Despite the limitations, the study is among the first to verify that ASD with motor dysfunction could be distinguished through features of movements in commercially available video games. Its results could help non-experts in motor function features to better understand and quantitatively describe the motor function difficulties of those with ASD.

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