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A Review of Autism Spectrum Disorder Diagnostic Tools

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Abstract: This is an overview of diagnostic tools implemented worldwide for Autism Spectrum Disorder (ASD). In this analysis, the benefits and disadvantages of each autism spectrum disorder diagnosis diagnostic technique are discussed. Pediatrists and psychiatric professionals who are focused on linguistic delay, brain function, or behavioural problems such as aggression, tantrum, etc. have currently noted the extent of impairments. The defects are assessed using multiple diagnostic tools. This review contrasts the seven forms of testing devices, including the Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview-Revised (ADI-R), Childhood Autism Rating Scale (CARS), Gillian Autism Rating Scale (GARS), Diagnostic Interview for Social and Communication Disorder (DISCO), Developmental, Dimensional & Diagnostic Interview (3DI), and Diagnostic and Statistical Manual of Mental Disorder (DSM). The advantages and limitations of each tool are discussed in detail.

Keywords: Autism Spectrum Disorder (ASD), diagnostic tools, ADOS, ADI-R, CARS, GARS, DISCO, 3DI, DSM-5

1. Introduction

In these recent years, the issue of Autism Spectrum Disorder (ASD) has become widespread. The cumulative prevalence of ASD is 1 in 68 girls, with a prevalence ratio of about four boys per 1 girl diagnosed, based on the Clinical Practice guidelines Management in Malaysia [1]. Anomaly is the precise cause of autism, although it is related to hereditary, environmental, and biological. ASD is a disorder of psychiatric diagnosis. It is characterized by social contact impairments, communication, and minimal or repeated patterns of behaviour. Diagnosis is based on existing methods of classification. Children have been diagnosed with ASD in recent years, rather than sub-classifications of those five primary fields comprising of discrepancies - not otherwise defined - that are Autism Condition, Asperger Syndrome, Rett Conditions, Childhood Disintegrative Disorders, and Pervasive Developmental Disorders. As for ASD diagnosis, using parent interviews, child behaviour evaluation, or a combination of both, all kinds of tests have been created. With the introduction of a diagnostic tool in the early twentieth century, ASD became an official diagnostic classification. By the diagnoses on different medical classifications, the word 'ASD' was in general use over a decade earlier.

The impairment was measured in three central domains: speech, social contact, and the existence of limited, repeated activities and interests. It is considered that a person with ASD has complicated neurobehavioral disorders that

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impair social contact and communication skills. It may also impact an infant's actions, with features such as minimal, repeated habits, interests, hobbies, and possible sensory sensitivities and challenging behaviours such as tantrums. The percentage of children with ASD to have intellectual disabilities are quite high. The word 'spectrum' in ASD reflects the vast variance in appearance, including co-morbidities, contributing to heterogeneity in the profile of problems and strengths in each person with autism. As the children had been diagnosed with ASD, the more readily identifiable symptoms frequently occur between 2 and 3 years of age. It can be diagnosed much sooner, in some examples. Failure to meet developmental goals will include immediate referral by the paediatrician of the infant or other health providers for developmental and behavioural evaluation. After a positive screening test, diagnostic tools are used to assess the existence or lack of autistic traits in a child when they show signs of this disorder. During a multidisciplinary examination, qualified clinicians typically prescribe them. They are more informative but often more time-consuming, and greater clinical knowledge is needed for their use.

2. Information of Each Diagnostic Tool

There are seven diagnostic tools are used to diagnose individuals who may be autistic. These include Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview-Revised (ADI-R), Childhood Autism Rating Scale (CARS), Gillian Autism Rating Scale (GARS), Interview for Social and Communication Disorder (DISCO), Developmental, Dimensional & Diagnostic Interview (3di) and Diagnostic and Statistical Manual of Mental Disorder (DSM). The related information of each diagnostic tool is discussed in this section.

2.1 Autism Diagnostic Observation Schedule (ADOS)

ADOS is published in 2000 by Western Psychological Services [28]. It was developed to examine social interaction, activity, and the use of imaginative minds. ADOS is an observation measure that can aid in the planning of education [2]. The ADOS was initially planned to be included in the combination by Autism Diagnosis Interview (ADI). It has become one of the standard assessment methods used by educational institutions and independent practitioners for intellectual disorder screening. ADOS is not commonly used to diagnose autism.

Nevertheless, it will provide a comprehensive and structured approach for recognizing children with ASD. The procedure involves making direct findings under regulated circumstances that other practitioners can imitate. Qualified clinicians should only administer ADOS medical screening, so it removes any of the conflicts of opinion that otherwise would be inevitable if two separate physicians give a diagnosis without meeting standard guidelines.

There are four different modules in ADOS. Each of these modules has been developed to provide an individual with a test at a particular age or functional level:

1.Module One – for those whose verbal communication skills are not sufficient. Utilizes fully non-verbal scoring situations.

2.Module Two – for those whose verbal communication skills are limited. This could involve young kids at age-appropriate levels of ability; most scenarios include wandering around the room and communicating with objects.

3.Module Three – for anyone who can interact with age-appropriate toys and are socially proficient. It may primarily be carried out on a desk or a table.

4.Module Four – for those who are articulate verbally but past the age of playing with toys. It contains some features of Module Three but also more conversational features related to daily life practices.

Each module has a set of standardized situations in which the tester investigates the subject. For instance, the presenter shows a picture that gives the child a template to position the blocks. The child is not deliberately presented with sufficient blocks to complete the task, but the tester shows that it has enough.

Do the kids inquire about the additional blocks? Pointing and shouting? Do not want to carry on? The examiner observed how the child approaches the problem, and each child's response brought the scoring actions to be measured by the examiner. Structured conversations or social scenarios, such as birthdays or sweets, are other elements. There are plenty of these that have small challenges, such as keeping the bricks and see how the child managed to cope with them.

To have responses, the examiner can use a hierarchy of systems called pressures. In general, in the preliminary evaluation stage, the patient must display effort without additional stimulation; if this does not happen, the interviewer may perform more and more complex activities to ensure a convincing function. This can make it difficult to track the exam, especially for parents. Many inspectors strongly forbid parents to be in the room during their child’s evaluation because parents can distract the diagnostic procedure.

The completion of each module in an ADOS takes about 30-45 minutes [32]. However, not all modules are usually included, and they are geared to specific kinds of topics for various behavioural and cognitive disorders. However, after discovering that the first one did not fit your child's practical ability closely enough to obtain an accurate result, the examinee can decide to use another module. The procedure is usually captured on camera for a team to review the test and diagnose it. This aims to remove subjective assumptions that are implicit in the practice of every single clinician.

The test subject's actions shall be between 0 and 3, and the usual conduct of a neurotypical individual doing the test shall be measured. Zero reflects normal behaviour, while 3 displays an irregular pattern. The average score on the evaluation module is the sum of the individual behaviour evaluations. Depending on the module and the age level, threshold levels can differ. For example, for an 8-year-old, a 13 scoring on Module 3 is perfectly natural but suggests an unsuccessful ASD for a 19-year-old.

Particularly after an ADOS test scoring is acquired, it is normal to seek out second opinions. It is important to remember that ADOS alone cannot be the primary criterion for developing a diagnosis that it cannot compensate for both stereotypes, interests, and development delay history. ADOS is also continually optimized and researched to make it more detailed and valuable. The test is being updated for the second time, and further experiments are underway.

2.2 Autism Diagnostic Interview-Revised (ADI-R)

Autism Diagnostic Interview-Revised (ADI-R) [3] is a half-structured assessment designed to evaluate the three main aspects of ASD: psychological, communication, and restricted behaviours or interests. The ADI-R is intended for people aged 18 months and older [29] and can be used for recovery and educational preparation, regardless of whether an ASD diagnosis is received. ADI-R is a standardized diagnostic tool used to evaluate autism, organize care, and discern from other mental disorder. This detailed interview has been used in decades of study that offers a thorough evaluation of persons suspected of getting ASD. It is proved to be very useful for both formal diagnosis and care and educational preparation. In the ADI-R, experienced clinical subjects will be interviewed with parents who are aware of the child's developing background and current actions. The interview will be utilized to analyze the child if their mental age is up to 2 years. The ADI-R consists of 93 items [30] and analyzed in three functional domains: language/communication, mutual social interaction and confined repetitive actions, and stereotyping.

Following highly detailed protocols, the interviewer records and codes the informant's response. Questions to the interview cover eight subject areas as follows:

1. History of the subject, including family, learning process, previous diagnosis, and medication.
2. Overview of the actions of the subject
3. Early growth and progressive milestones
4. Language learning and loss of language or other skills
5. Present functioning in terms of language and contact
6. Social growth and playing
7. Interests and actions
8. Clinically related actions such as aggression, self-injury, and suspected epileptic characteristics

Usually, ADI-R management and scoring require approximately 1.5 to 2.5 hours [33]. The results can now be recorded and only using a single form. The ADI-R consists of algorithms called Diagnostic Algorithms and Current Behaviour Algorithms. The Systematic Algorithm allows the estimation and analysis of each of the five age-specific ADI-R algorithms; two Developmental Background Diagnostic Algorithms and the Structured Diagnostic Algorithms, and three Current Behaviour Algorithms based on current functioning and used for care and educational preparation.

Since ADI-R is an interview session, it offers categorical outcomes rather than scales or criteria. The results can support the diagnosis of autism or assess the clinical needs of ASD prediction. ADI-R helps to differentiate and determine autism conditions, defining new subgroups, and quantifying autistic symptomatology. The widespread usage of ADI-R in the international research community has shown clear evidence of its categorical findings' reliability and validity.

2.3 Childhood Autism Rating Scale (Cars)

CARS [4] is an observation tool intended to classify children with autism relative to other developmental disorders and to assess the severity of symptoms. It was designed by Eric Schopler, Robert Reichler, and Barbara Rochen Renner [31]. CARS are developed to help diagnose autism in children over two years of age [34]. Items for CARS have been derived from five separate theoretical viewpoints on autism. It is still not possible to specifically discern Asperger's disorder or pervasive developmental conditions. However, as the researcher [5] points out, CARS was developed before the definition of the autism spectrum.

A wide range of tests performed is used to help diagnose autism. The distinction between CARS and other behavioural rating instruments is whether the child has autism or other developmental delay conditions such as mental retardation. It helps health professionals, educators, and parents to recognize and classify children with autism. CARS works by assessing the child's behaviour, attributes, and abilities against a typical child's predicted developmental growth. As specified in the CARS, the characteristics to be evaluated are as follows:

1. Relationship with person
2. Imitation
3. Emotional reaction
4. Usage of the body
5. Use entity

6. Adaptation for transition
7. Visual reply
8. Listening to the answer
9. Taste-smell-touch reaction and use
10. Fear and anxiety
11. Verbal interaction
12. Non-verbal contact
13. Level of activity
14. Intellectual response level and accuracy
15. Overall imitations

The evaluation is accomplished by a health care worker, a teacher, or a parent by rating the child's actions from 1 to 4. In the CARS evaluation form, rating 1 is normal, rating 2 is slightly abnormal, rating 3 is moderately abnormal and rating 4 is extremely abnormal. Total scores range from 15 to 60, with 30 being the cut-off point can diagnose autism. Mild to moderate is indicate between scores 30-37, while scores between 38 and 60 indicate extreme autism. Although the CARS type can be easily downloaded or accessed from the Internet, it is not recommended to use it to test the child on our own. It is also best to seek clinical assistance in understanding the outcome of the CARS of the infant. Continuously and intense observation of the child is necessary throughout completing the CARS. The parent or teacher, or medical practitioner should have a clear understanding of the requirements so those correct outcomes can also be achieved. CARS is typically used for children 2 years of age or older.

It is crucial to highlight that CARS is not a standardized test and does not score independently of the clinical judgment, which is an essential component of the CARS score and affects the outcome score.

2.4 Gillian Autism Rating Scale (Gars)

The Gilliam Autism Rating Scale (GARS) [6] is a 42-item standard-referenced screening tool used for persons aged 3 years and older who have severe behavioural issues that may suggest autism. GARS is designed to help clinicians recognize the Autism Spectrum Disorder in a person and help educational teams decide whether a child can meet the educational requirements for obtaining special education services in the ASD group. It is necessary to clarify that this is not a medical diagnosis but rather a category for the provision of special education services. GARS collects information on characteristics, usually in the three areas of Stereotyping Activity, Communication, and Social Interaction, and contains a history of development. It was utterly standardized for people diagnosed as autistic. Standard ratings and percentages are given, and the probability of autism can be assessed.

GARS-2 is a modification of the widely used Gilliam Autism Rating Scale (GARS). It was developed to help counsellors, teachers, parents, and physicians recognize and diagnose autism in people between the ages of 3 and 22 years and to estimate the seriousness of the condition. GARS-2 can be administered individually in 5 to 10 minutes and consists of 42 items illustrating the typical behaviour of people with autism. Items are classified into three subscales based on two descriptions of autism, one from the Autism Society of America and the other from the diagnostic criteria for autistic disorder published in the DSM-IV-TR, Stereotyping Activity, Communication, and Social Interaction. The subscale standard scores are summed up to generate the Autism Index (mean = 100, SD = 15). Higher quality scores and Autism scores are predictive of more troublesome behaviour. The rating also involves the Likelihood of Autism Classification of Very Likely, Probably, and Avoidably.

2.5 Diagnostic Interview For Social And Communication Disorder (DISCO)

The Diagnostic Interview for Social and Communication Disorder (DISCO) was developed and tested to help identify individuals with ASD at all ages, from childhood to old age and at all stages of ability. It is a half-structured interview designed by Dr. Lorna Wing and Dr. Judith [7] to portray the whole person from early years to the present day. The primary goal is to promote the comprehension of the pattern of social activity and communication over time and the abilities and impairments that underlie an individual's overt behaviour. In this way, it is possible to classify all aspects of the autism spectrum from the most apparent to the subtler.

DISCO uses a dimensional approach to evaluation rather than arbitrary cut-off points and putting people in different groups. This dimensional approach to clinical explanation is far more useful for recognizing needs. DISCO's special benefit is that it helps to gather knowledge about all facets of everyone’s abilities and behaviour, not just the symptoms of autism spectrum disorder.

Detailed information is collected to represent both the evolution of the person over time and the current picture. However, when there is no informant available to provide an early past, it is possible to complete the schedule items for existing skills and actions based on the current presentation. This is advantageous over certain other diagnostic schedules as it allows for more flexible use of the DISCO diagnostic system. It also offers information on other possible developmental, psychological, or psychiatric conditions.

2.6 Developmental, Dimensional & Diagnostic Interview (3di)

Researchers [8] created a parental autism interview called Developmental Diagnostic Dimensional Interview (3DI) that could be administered to non-selected clinical and general population populations that measure both symptom severity and comorbidity across the broad range of the autistic spectrum. 3DI offers a short, structured parenting interview for the diagnosis of ASD. This is a ground-breaking, computer-based interview for the diagnosis of autism and associated disorders in children [9]. The main features of the 3DI include compute the severity of features associated with a diagnosis of autism

1.Computes levels of behavioural change
2.Establishes comorbidity through a wide range of child psychiatric conditions
3.Allows an assessment for autism in as little as 45 minutes
4.Creates a detailed report that is sufficient for parents and referrers
5.Like from parents
6.Excellent reliability and validity of the criteria defined concerning the ADI-R
7.No double-entry: all data can be exported to SPSS for analysis purposes
8.Provides an audit trail that is indispensable for medical authority

3DI is a well-validated, accurate ASD diagnostic tool. Also, it is vital to carry out a dimensional and rapid evaluation of the difficulties of social contact in the group and clinical sample for research purposes.

2.7 Diagnostic And Statistical Manual Of Mental Disorder (DSM)

The DSM stands for the Diagnostic and Statistical Manual of Mental Illness. It is written by the American Psychiatric Association and encompasses all kinds of mental health issues [10]. For clinical diagnosis, treatment guidelines and assurance purposes, DSM is widely used in the United States and performed by physicians and psychologists. The DSM focuses predominantly on explaining the symptoms and the most severely affected gender by the mental disorder, the average age of onset, the results of treatment, and rehabilitation methods.

1.The DSM-IV [11] has been published in 1994 and contained more than 250 mental illnesses. The revised edition, DSM-IV-TR, was released in 2000, including slight changes in the definitions of each disorder. The medical professional utilized the manual as a method for assessment and diagnosis. The multiaxial use five different dimensions to define disorders. This approach was designed to help physicians and psychologists carry out systematic assessments of the child's functioning level since mental illness frequently affects many different aspects of life.

2.Axis I: Clinical Syndromes

- Medical symptoms that cause severe disability have been identified. Disorders have been classified into various groups, such as mood disorders.

3.Axis II: Personality and Mental Retardation

- Identified long-term functional issues that were not known to be discreet Axis I disorder. Personality conditions cause significant issues with responding to the environment, antisocial personality disorder and histrionic personality disorder. Mental retardation is marked by intellectual disability and deficiencies in areas such as self-care and interpersonal skills.

4.Axis III: Medical Conditions

- Includes physical and medical problems that cause or exacerbate Axis 1 and Axis II disorders such as HIV/AIDS and damage to the brain.

5.Axis IV: Psychosocial and Environmental Problems

- Any social or environmental issues that may influence Axis I or Axis II disorders. The example topics like unemployment, relocation, and divorce.

6.Axis V: Global Assessment of Functioning

- Enabled the clinician to rate the overall level of functioning of the client. Based on this evaluation, doctors could better understand how the other four axes worked and the effects on the individual's existence.

In 2013, the current version known as the DSM-5 was released; it lays out the criteria for making an autism spectrum diagnosis that any psychologist or therapist can use whatever methods they deem to be successful. The DSM-5 incorporates a variety of significant improvements from the previous DSM-IV. The most immediate change is the transition from Roman numerals to Arabic numerals. Maybe most importantly, the DSM-5 abolished the axis system instead of listing types of disorders along with a variety of associated disorders. Examples of categories used in the DSM-5 include anxiety disorders, psychotic and related disorders, depressive disorders, eating and eating disorders, obsessive-compulsive and related disorders, and personality disorders. Other improvements to the DSM-5 include the following:

1.Asperger's condition has been excluded and merged into the autism spectrum disorders classification.
2.Disruptive mood disorder has been introduced, in part to minimize over-diagnosis of childhood bipolar disorders.

3.Several diagnostics were formally added to the manual, including binge eating disorder, hoarding disorder, and premenstrual dysphoric disorder.

While DSM is an effective tool, only those who have undergone advanced training and have adequate expertise are eligible to diagnose and treat mental illness. Mental health practitioners often use DSM to categorize patients for billing purposes. As with most medical conditions, the government and several insurance providers need a clear diagnosis to accept treatment payment.

The two parameters accessed and used in DSM - 5 are social contact and constrained repetitive behaviours and interests. Inconsistent use of ASD-related diagnostic classification terminology has created uncertainty in clinical care and access to resources. It has complicated both the execution of research studies and the implementation of research results. 'Dimensional elements' are now used (DSM-5) to diagnose any ASD that shows how much someone's disease affects them across a wide spectrum of domains. This helps to determine how much support a person needs. ASD is a behaviourally specified category of disorders that is heterogeneous in both cause and manifestation. The NICE Guidelines include guidance for identifying, referral, and diagnosing ASD in England, Wales, and Northern Ireland. This is given in Scotland by the SIGN Guidelines.

3. Comparison of Each Diagnostic Tool

The majority of the diagnostic tools have communication and social conditions questionnaires containing from 10 to 70 items. Furthermore, most of the tools are not publicly accessed on the internet. Table 1 below shows the advantages and disadvantages of autism diagnostic tools. Meanwhile, in Table 2 shows the summary studies of ASD diagnostic tools.

Table 1 - Advantages and Disadvantages of Autism Diagnostic Tools

No	Tool	Advantages	Disadvantages
1	Autism Diagnostic Observation Schedule (ADOS II)	• Use to assist in educational planning	• Not used as a stand-alone diagnostic measure. • To depend on self-report during the in-person evaluation.
2	Autism Diagnostic Interview-Revised (ADI-R)	• Can be used as treatment and educational planning • Adds some objectivity, standardization, and continuity to the clinical decision-making process. • Offers a standardized format to ensure all relevant forms of historical information are recorded, organized, and explained. • An interview allows parents to have a better understanding of the factors being examined. • Related to DSM-IV diagnostic criteria and current understanding of autism among children 3-5 years of age. • A homogeneous scoring algorithm. • Necessary sensitivity and accuracy when administered by highly skilled individuals.	• The results of false positive and false negative tests can be false • Not been examined in the diagnosis of autism in children under the age of three. • ADI-R undergo rigorous and costly training in the administration. • Test administration takes a lot of time for both experts and parents.
3	Childhood Autism Rating Scale (CARS)	• Adds a certain degree of objectivity, standardization, and continuity to the clinical decision-making process. • Provides a structured format for gathering and recording	• Test results may be false positive and false negative • Not identify some children with milder presentations of autism.

		information. • Useful for children as young as two years of age. • Sensitivity and accuracy to assess the severity of autism symptoms when performed by highly qualified individuals. • Instructional materials for administration and interpretation are readily accessible.	• Incorrectly identify autism in children • Sensitivity and accuracy have not been demonstrated in the absence of highly qualified rates. • Does not completely reflect existing information on the cognitive and social growth of young children.

Table 1 - (Continued)

No	Tool	• Advantages	• Disadvantages
4	Gillian Autism Rating Scale (GARS)	• Suitable for 3 to 22 years old ASD patients. • 2nd version of GARS displays high sensitivity, accuracy, and positive predictive value to classify people with autism. • GARS-2 had been updated from GARS with updated standardized set • The tool is quite simple to use and taking short time to complete. • Can be conducted without examiners, the ratings can be completed by anyone who knows the individuals well.	• Only a small sample taken from age 16 to 22 years old, which may come with difficulties for the older age groups. [24] • Did not include a further clarification such as history of language development and IQ progress. • Need extra caution if the informant cannot give complete information.
5	Diagnostic Interview for Social and Communication Disorder (DISCO)	• Suitable for all ages, communication skills, and mental ages. • For adult case, even there are no information on his/her early age, the diagnosis still can be completed based on untypical behaviour and current social skills. • Provide the individual current skills, disabilities, and rehabilitation planning.	• Need expert clinician to conduct the diagnosis • The studies based on this tool does not include adolescents and adults as a sample. • Based on Wing and Leekham et al., [7], no validation occurred whether it is one interviewer with the two different informants concerning the same child or vice versa.
6	Developmental, Dimensional & Diagnostic Interview (3di)	• The reliability is quite high especially taken from ASD individual with normal range IQ. • The assessment uses informal style that reduce total interviewing time.	• The studies are limited to several sample of mental disorders and only using mild autistic case. • Advised to combine the 3di with other independent assessment such as ADOS and ADI-R.
7	Diagnostic and Statistical Manual of Mental Disorder (DSM-5)	• The specificity of DSM-5 was high compared to DSM-IV • The assessment can detect the severity level of the ASD, and types of rehabilitation needed. • Have additional assessment for other genetic mental disorder such	• The DSM-5 methods are disorganized that cause the proceedings were undoubtful, secretive, and unopened to the other influences. • The DSM-5 has appalling

		as Rett syndrome. • Include new social communication diagnosis for individuals without repetitive behaviour.	writing mistakes because it writes by unexperienced person in writing diagnosing criteria.

Table 2 - Summary studies of ASD diagnostic tools

References	Tools	Sample size (ASD; non-ASD)	Age	Findings			
				Sensitivity	Specificity	Area Under Curve (AUC)	Correct Classification (cc)
Risi et al., 2006 [35]	ADOS	227; 43	<36 months	86%	84%	NR	NR
Risi et al., 2006 [35]		57; 10	36-112 months	96%	20%	NR	80%
Ventola et al., 2006 [36]		36; 9	16-31 months	97%	67%	NR	NR
Mazefsky et al., 2006 [37]		56; 19	22 months – 8 years	93%	84%	NR	NR
Klein Tasman et al., 2007 [38]		52; 22	22+ months	87%	78%	NR	82%

Table 2 - (Continued)

References	Tools	Sample size (ASD; non-ASD)	Age	Findings			
				Sensitivity	Specificity	Area Under Curve (AUC)	Correct Classification (cc)
Kleiman et al., 2008 [39]		46; 10	22+ months	88%	80%	NR	84%
Gray et al., 2008 [40]		139; 56	20-55 months	76%	94%	NR	NR
Le Couteur et al., 2008 [41]		77; 24	24-49 months	83%	100%	NR	NR
Gotham et al., 2007 [42]		912; 349	22+ months	74%	74%	NR	74%
Wiggins et al., 2008 [43]		73; 69	16-37 months	96%	65%	NR	65%
Papanikolaou et al., 2009 [44]		77 sample	22+ months	87%	84%	NR	86%
Oosterling et al., 2010 [45]		143; 65	20-40 months	77%	83%	NR	NR
Kim and Lord 2012 [46]		123; 28	21-47 months	98%	64%	NR	NR

Kim and Lord 2012 [46]		69; 41	21-47 months	97%	68%	NR	NR
Corsello et al., 2013 [47]		98; 20	24-36 months	97%	85%	NR	NR
Hus et al., 2014 [48]		437; 90	9-55 years	91%	82%	NR	NR
De Bildt et al., 2016 [49]		38; 21	18-66 years	61%	NR	66%	NR
Pugliese et al., 2015 [50]		253; 68	11-61 years	85%	71%	NR	NR
Langmann et al., 2017 [51]		165; 191	12-68 years	86.8%	80.1%	NR	NR
Fusar-Poli et al., 2017 [52]		78; 35	18-55 years	85.9%	82.9%	84%	85%
Maddox et al., 2017 [53]		6; 69	>18 years	100%	74%	NR	NR
Kamp Becker et al., 2018 [54]		189	<6 years	NR	NR	78.1%	NR
Randall et al., 2018 [55]		44; 52	<6 years	94%	80%	NR	NR
Ventola et al., 2006 [36]	ADI-R	36; 9	16-31 months	53%	67%	NR	NR
Gray et al., 2007 [40]		143; 66	20-55 months	73%	77%	NR	NR
Wiggins et al., 2008 [43]		73; 69	16-37 months	33%	94%	NR	NR

* NR: Not Reported

Table 2 - (Continued)

References	**Tools**	**Sample size (ASD; non-ASD)**	**Age**	**Findings**			
				Sensitivity	**Specificity**	**Area Under Curve (AUC)**	**Correct Classification (cc)**
Oosterling et al., 2010 [45]		143; 65	20-40 months	75%	63%	NR	NR
Christiansz et al., 2016 [56]		126; 59	20-55 months	95%	36%	NR	NR
Randall 2018 et al., 2018 [55]		355; 42	<6 years	52%	84%	NR	NR
Fusar-Poli et al., 2017 [52]		78; 35	18-55 years	43%	95%	69%	NR

Ventola et al., 2006 [36]	CARS	36; 9	16-31 months	89%	100%	NR	NR
Wiggins et al., 2008 [43]		73; 69	16-37 months	71%	93%	NR	NR
Chlebowski et al., 2010 [57]		236; 118	26 months	66%	96%	NR	NR
Russell et al., 2010 [58]		86; 14	61 months	87%	21%	81%	82.52%
Randall et al., 2018 [55]		148; 31	<6 years	80%	88%	NR	NR
South et al., 2002 [59]	GARS	119 ASD	3-10.5 years	48%	NR	NR	NR
Lecavalier 2005 [60]		284 ASD	3-21 years	38%	NR	NR	NR
Mazefsky and Osward 2006 [37]		59; 19	22 months- 8 years	39%	61%	NR	NR
R. C. Eaves et al., 2006 [61]		111; 23	3-26 years	79%	68%	NR	NR
Sikora et al., 2008 [62]		79; 50	17-71 months	53%	54%	NR	NR
Hampton et al., 2015 [63]		652; 92	1.5-5 years	49%	60%	NR	NR
Leekam et al., 2002 [64]	DISCO	33 ASD	35 months-140 months	98%	57%	78%	NR
Wing et al., 2002 [65]		22 ASD	80-133 months	NR	NR	NR	NR
Nygren et al., 2009 [66]		91 ASD	2.8-40 years	NR	NR	NR	NR
Kent, Carrington et al., 2013 [67]		36; 46	34-140 months	100%	67%	84%	NR
S. J. Carrington et al., 2014 [68]		36; 46	34-140 months	100%	71%	86%	NR
S. Carrington et al., 2015 [69]		82; 31	34-140 months	97%	87%	92%	NR

* NR: Not Reported

Table 2 - (Continued)

References	**Tools**	**Sample size (ASD; non-**	**Age**	**Findings**			
				Sensitivity	**Specificity**	**Area Under Curve**	**Correct Classificatio**

		ASD)				**(AUC)**	**n (cc)**
Skuse et al., 2004 [70]	3di	60; 60	2-21 years	100%	97%	NR	99%
Santosh et al., 2009 [71]		244; 196	2-21 years	100%	98%	NR	99%
Chuthapisith et al., 2012 [72]		63; 67	5-6 years	76.2%	80.9%	89%	NR
Lai et al., 2015 [73]		44; 25	6-12 years	95%	77%	NR	NR
Duvekot et al., 2015 [74]		134 ASD	4-10 years	85%	83%	NR	NR
Slappendel et al.,2016 [75]		51; 42	2.5-6 years	84%	54%	NR	NR
Mandy et al., 2018 [76]		39; 29	18-59 years	95%	92%	NR	NR

* NR: Not Reported

4. ASD Research Using Supervised Machine Learning

Classification algorithms designed to classify a correct diagnosis for autism are part of the supervised learning research discussed in this article. All the research mentioned in this study has implemented various supervised learning approaches, with several outstanding output models arising from the research. A related machine learning algorithm results in reporting success of different models, such as support vector machine (SVM) algorithms, alternating decision tree (ADTree), random forest, and logistic regression. In conjunction, each of these approaches will be discussed.

4.1 Support Vector Machine (Svm)

SVM also well-known as maximum margin classifier is a supervised learning algorithm, suitable for the ideal hyperplane in n-dimensional space, to use the independent variables in the data set to correctly identify the class [22][23]. Maximum margin classifier [26] means that it can effectively maximize the difference between n data sets in a high-dimensional space. In this research, the SVM algorithm is used to identify people based on a standardized assessment, genetics, neuroimaging, and other measurement methods.

Through ASD research, machine learning algorithms such as SVM had been used to optimize screening and diagnostic classification. Bone et al. [12] apply the SVM classifier with cross-validation based on two standardized assessments, which are ADI-R and the Social Responsiveness Scale (SRS). The sample contained of 1,264 people with ASD and 462 people with a non-ASD mental disorder. Participants were separated into two categories: participants above ten years old and people below ten years old. The specificity results for participants above 10 years old and under ten years old are 89.2 % and 86.7 %, respectively. An accuracy of 59 % was registered for participants above ten years old and 53.4 % under 10 years old. These results indicate that machine learning should be implemented to enhance the precision of ASD diagnosis.

4.2 Alternating Decision Tree (Adtree)

ADTree models merge a variety of decision trees [27] to represent one decision node for binary classification. One of the key advantages of Decision Tree is each element can be processed regarding its effectiveness. In the ASD literature review, ADTree models have been used to improve diagnostic and screening procedures.

Wall et al. [13] defined some ADI-R elements that could accelerate the ASD diagnosis. The test from the dataset contains 891 participants with ASD and 75 participants with non-ASD. An ADTree classifier gains an accuracy of 99.9 % using seven out of the 93 ADI-R elements only. Then, the seven-item classifier was further investigated with 1654 ASD cases and 322 non-ASD cases. Based on all the samples, the classifier achieved almost 100 % of precision. In a related analysis, Wall et al. apply ADOS element that could significantly be reliable in diagnosing ASD. Module one of ADOS containing 612 ASD individuals and 15 ASD non-ASD individuals was imbued in the first study. An ADTree classifier achieve superior results with a classification accuracy of 100% using only eight of the 29 elements in module one of ADOS. Using extra samples of 110 ASD, 366 non-ASD, and 1000 artificial controls, the eight-item classifier was further validated. The eight-item classifier has been shown to have a sensitivity of 100 % in all ASD samples. A specificity of 94 % was revealed using the simulated control information. Wall and colleagues' results from these two experiments indicate the potential of machine learning methods to substantially reduce the tool evaluation items required to predict ASD.

4.3 Random Forest

Random Forest (RF) is a form of supervised learning that utilizes several regression and classification approaches. The classification is occurred based the tree's projections. The built-in bootstrapping is an advantageous function of using an RF, leading to the algorithm being qualified and tested with less inherent bias in the analysis. By changing the number of inputs for each tree split and the number of trees, the algorithm can reach its optimal tuning parameters. The combined preparation and evaluation implicit in the algorithm would also have a beneficial impact on minimizing the overfitting risk.

Abbas et al. [14] perform two different algorithms and merged into one classifier to construct an ASD classification system focused on the parental evaluation forms and the home videos' activities. For children aged 18 to 84 months, ADI-R and ADOS scores were built from various libraries and used to train RFs for parental survey questions and RF video classifiers, respectively. ADI-R interviews were conducted to an arbitrary group of low-risk ASD children to help balance the results. As language acquisition also influences the ASD cases, the classifiers have been performed independently on children below or above 4 years old. The parental classifier was implemented in 2299 children with ASD, 100 children with TD and 287 children with other conditions. The video classifier was trained on 3310 children with ASD, 585 children with TD and 364 children with the different disorder.

4.4 Logistic Regression

Logistic regression is a mathematical model using a logistic function in its simple form to model a binary dependent variable. The variables may be in discrete or continuous form and are utilized to estimate the probabilities of a given binary value being taken from the target score.

Kosmicki et al. [15] assigned out to evaluate whether ASD could be reliably identified and measured by the ADOS modules two and three parts. The dataset contained ADOS scores of 4540 users. Module two of the ADOS was completed by 1451 people with ASD and 348 non-ASD, and module three was completed by a further 2434 people with ASD and 307 non-ASD. A ridge regression performed better in correctly classifying ASDs with a precision of 98.27 %, 98.81 % sensitivity and 89.39 % specificity, using nine of the 28 behaviours assessed within module two. Table 3 below summarized all the findings that imply machine learning to the behavioural datasets.

Table 3 - Summary of ASD research using machine learning

Reference	Dataset type	Sample size	Method	Prediction classes	Accuracy (%)
Wall et al., 2012a [16]	ADI-R	2867 ASD; 92 non-ASD; 1000 artificial controls	ADTree	ASD and non-ASD	100
Wall et al., 2012b [13]	ADOS	1058 ASD; 15 non-ASD; 1000 artificial controls	ADTree	ASD and non-ASD	-
Jiao et al., 2012 [17]	CARS and SNP	118 ASD	Decision tree	ASD symptoms severity	67
Duda et al., 2014 [18]	ADOS	2333 ASD; 283 non-ASD	ADTree	ASD and non-ASD	97
Bone et al., 2015 [12]	ADI-R and ADOS	3392 ASD; 474 non-ASD	ADTree	ASD and non-ASD	-
Kosmicki et al., 2015 [15]	ADOS-2	3885 ASD; 665 non-ASD	ADTree; SVM; ridge regression	ASD and non-ASD	98
Duda et al.,	ADI-R	891 ASD; 75	ADTree	ASD and non-	-

2016a [18]	non-ASD	ASD

Table 3 - (Continued)

Reference	Dataset type	Sample size	Method	Prediction classes	Accuracy (%)
Duda et al., 2016b [19]	SRS	2798 ASD; 170 ADHD	LASSO; SVM; ridge regression; linear discriminant analysis	ASD and ADHD	97
Moradi et al., 2017 [20]	ADOS	156 ASD	ENet; SVR	ASD symptoms severity	-
Duda et al., 2017 [21]	SRS	3023 ASD; 324 ADHD	LASSO; SVM; ridge regression; linear discriminant analysis	ASD and ADHD	90
Abbas et al., 2018 [14]	ADI-R; ADOS	3310 ASD; 585 TD; 364 other DD	Random forest; logistic regression	ASD and non-ASD	-

5. Discussion

Autism spectrum disorder (ASD) diagnosis is difficult due to the condition's broad range and dependence on behavioral symptoms and indicators. Instead of using diagnostic tests alone, current recommended diagnostic practice requires that information from clinical assessment, child care, or educational settings, as well as standardised instruments (especially for developmental or intellectual ability), be included, with diagnostic assessment tests for autism as optional additions. A systematic review had been conducted to compare the advantages and disadvantages of Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview-Revised (ADI-R), Childhood Autism Rating Scale (CARS), Gillian Autism Rating Scale (GARS), Interview for Social and Communication Disorder (DISCO), Developmental, Dimensional & Diagnostic Interview (3di) and Diagnostic and Statistical Manual of Mental Disorder (DSM).

Recent research in 2018 [54, 55] shows that ADOS in a child who does not have ASD is better for not losing children with ASD and is like CARS and ADI-R in not misdiagnosing ASD. In populations with a high ASD occurrence, ADOS has acceptable accuracy. Over evaluation, however, is possible if the technique is used in societies with a lower ASD prevalence. This result supports the current recommended protocol to be used as part of a multidisciplinary test rather than as stand-alone testing methods for ASD diagnostic tools.

The popular supervised machine learning algorithms in the previous ASD research studies were SVM [12] and ADtree [13]. In this research, supervised machine learning algorithms were used to indicate binary predictions (often based on diagnosis) for ASD. The results discussed in this article suggest that in ASD research, there is considerable importance in and functional implementations of supervised machine learning. Through ASD research, the data collection instruments accessibility has eased access to machine learning application. An escalating number of supervised academic studies on machine learning has arisen in the field of ASD in the last decade.

6. Conclusion

Diagnosing the autism spectrum disorder (ASD) is not straightforward owing to the wide spectrum of the condition and reliance on behavioural symptoms and signs. Current recommended diagnostic practice requires that information from clinical assessment, childcare, educational settings, and standardized instruments (especially rather than diagnostic tests alone. This assessment requires a multidisciplinary team consisting of several health professionals and often is time-consuming with limited availability of resources. However, accurate diagnosis is critical. If the diagnosis is inaccurate, young children who have ASD and who are not given the diagnosis will fail to receive early interventions that may provide them and their families with valuable strategies to facilitate their development and manage their behaviours. Besides, an inaccurate diagnosis may result in children who do not have ASD receiving an ASD diagnosis, which could have an unfavourable effect for the child and the family and may result in misallocation of limited-service resources.

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