# Brain-Computer Interfaces in Autism Therapy and Diagnosis: A Review of Emerging Trends and Innovations

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**Abstract:** Autism Spectrum disease (ASD) is a multifaceted neurodevelopmental disease marked by challenges with social interaction, communication, and repetition. Although long used, conventional methods of treating and diagnosing autism spectrum disorder (ASD) are sometimes overshadowed by issues of subjectivity, late detection, and restrictions on individualization. Increased attention has been given to Brain-Computer Interface (BCI) technology as a method for increased diagnosis and treatment strategy for autism spectrum disorder (ASD). Electroencephalography (EEG) is a typical technique employed by brain control devices (BCIs) to record and process brain waves, which are able to reflect neural activity in real time. For an early and accurate diagnosis of autism spectrum disorder (ASD) and identification of accompanying anomalies, such insights are important. Neurofeedback training, interactive VR-BCI systems, and emotion recognition modules are all some examples of brain-computer interface (BCI) therapies that are promising in improving the attention, emotion regulation, and social communication of autistic individuals. Ethical issues, technological constraints, and interdisciplinary collaboration needs are some of the challenges this study discusses as it ventures into the possible applications of brain-computer interface (BCI) technology to diagnose and treat autism spectrum disorder (ASD). The coming together of machine learning, multimodal neuroimaging, and wearable BCI systems all point to a revolutionary future in which BCIs are vital for providing personalized and accessible autism care.

**Keywords:** Autism Spectrum Disorder, Neurotechnology, Virtual Reality, Emotion Recognition, Artificial Intelligence, Cognitive Rehabilitation, Assistive Technology

## I. Introduction

Social interaction, communication, and certain behavioral patterns are longstanding difficulties experienced by individuals with Autism Spectrum Disorder (ASD) (Wong, A., Gao, R. 2023). Making a diagnosis of autism spectrum disorder (ASD) is not always easy. In spite of being limited, age-old methods of diagnosis like clinical observation and questionnaire evaluation have been integral to medical care for decades. Clinical observation requires the time-consuming and subjective activity of prolonged surveillance and evaluation by medical professionals. Questionnaires, due to being dependent upon accounts by patients or carers, are prone to recollection bias and subjective interpretation. Better and more reliable diagnostic tools are severely needed now to assist in early diagnosis and speedy treatment of autism spectrum disorder (ASD) as reported cases continue to increase. The treatment as well as diagnosis of autism spectrum disorder (ASD) are being revolutionized by new Brain Computer Interface (BCI) technology. Capturing and decoding neural signals in real time, BCI systems take a shortcut past older methods, establishing an immediate link of communication between equipment and brain. Enhanced objectivity and real time tracking are two of its advantages, as this technique gives a direct window into one's cerebral activity patterns. Evidence in studies by electroencephalogram (EEG) indicates that individuals with autism spectrum disorder (ASD) exhibit specific brain activity characteristics in language and social interactions. Analyzing such neural signals, BCI systems can recognize ASD-specific associated EEG profiles and hence make more precise and quick diagnoses. Through real-time observations that guide development of specific therapeutic interventions, BCI facilitates persistent observation of neurological activity.

The possibility of BCI technology as a new tool in ASD diagnosis has been shown by studies that use EEG data to distinguish, with success, ASD individuals from normal controls. Another potential new application of BCI is in autism spectrum disorder (ASD) rehabilitation, in which it gives immediate feedback in order to enhance individuals with the disorder in terms of communication and social ability. Yaoyao et al. (2024) asserts that the aim of this research is to analyze current as well as potential uses of BCI in autism spectrum disorder (ASD) diagnosis. The current work examines how BCI technology can obtain and read out brain activity in a direct manner, resulting in more objective as well as more precise data relating to neural activity. The complexity of ASD, in combination with limitations of gold-standard diagnostic techniques (e.g., subjectivity and late onset of symptoms) creates a potential new opportunity in terms of ASD early diagnosis as well as customized therapy.

## II. Overview of Autism Spectrum Disorder and Its Co-Occurrence with ADHD

### What is Autism?

Over the past half-century, autism has been steadily increasing in prevalence, much like cancer. As it is, one out of every forty-four children is on the spectrum (CDC, 2022). Complex neurological illness known as autism spectrum disorder (ASD) causes developmental disability on multiple levels, including impairments in social behavior, language, speech, and communication. There has been a disturbing uptick in the global prevalence statistics of autism. The impact on boys is four times greater than that on girls. Autism spectrum disorder is caused by over a thousand genes. Disabilities stem from individual variances in brain structure, perception, and function (DSM-5, 2013).

These individuals perceive, behave, learn, and communicate in ways that differ from the norm due to differences in brain wiring. The term "Neurodiverse" is becoming prominent in educational and social structures, and it is being used more and more to talk about individuals with autism spectrum disorder and other types of neurodiversity. They hold that when you gaze upon an autistic person, then what you see is an autistic person, and that's what so hard it is to understand autism. There is a 'spectrum' of such degree and scale. Individuals who are diagnosed with ASD might struggle with anything from minor difficulties in life to profound disability. A child is typically diagnosed with autism at 30 months to age three. Now, though, criteria for diagnosing developmental delay in milestones can be applied to children as young as nine months. CDC (2022). Even among children who meet age-two milestones, regress can happen.

Even in people who are capable of being semi-independent, staying in touch, having friendships and even work becomes complicated. "High functioning" is what this term describes. The subgroups of autistics are often characterized by similar qualities, such as trouble socially, in communication, in learning, and in school performance. The symptoms of autism can be generally categorized as five different disorders: Asperger's, Rett, Kanner, and PDD-NOS (persistent developmental disorder). They all possess a different combination of difficulties as well as differing scopes of disability. Individuals are often also termed as being High or Low Functioning, Verbal or Nonverbal, and so forth, based upon how much and how quickly they are expected to learn and succeed in school. But labels in and of themselves will never reveal anything about the person who is on the spectrum. The diagnosis of autism in children by paediatricians is being added at a rate that is alarming, per statistics by both the World Health Organization and the Centers for Disease Control and Prevention.

### Autism spectrum disorder (ASD)

Autism spectrum disorder (ASD) as a neurodevelopmental disorder is marked by limited, repetitive behavior, interests, or activity, as well as anomalies of communication in social situations (American Psychiatric Association, 2013). Specific indications of added clinical features, such as in attention deficit hyperactivity disorder (ADHD), are typically employed in diagnosing autism spectrum disorder (ASD) and it is not rare to encounter neurodevelopmental disorders occurring in tandem (American Psychiatric

Association, 2013). Interference in attention, disorganization, and/or hyperactivity-impulsivity that does not conform to an individual's age of development is typical of attention deficit hyperactivity disorder (ADHD) (American Psychiatric Association, 2013).

Social interaction, speech (both spoken and nonverbal) disorders, and limited/repetitive activity patterns are characteristics of autism spectrum disorder (ASD). Certain symptoms of autism are lack of eye contact, failure to understand social signals, and repetitive hand flapping or object lining up. Individuals usually develop increased sensitivity to specific sounds, lighting, sensation, or taste. A combination of hereditary and environmental factors is what is known by research to develop autism, though there is no known reason. Contrary to what is popularly believed, it does not relate to maternal approach behavior or immunization. Detection early in life is critical in successful intervention, and symptoms typically develop before age three.

Treatment and interventions in autism spectrum disorder (ASD) are aimed at enhancing social behavior, speech, and learning rather than cures. Therapy in favor of children who are autistic usually involves behavior therapies, speech and occupational therapy, special educational plans, and so forth. Medicine might be given to manage linked conditions such as anxiety, hyperactivity, or sleep disorders. Individuals who are autistic are capable of enjoying productive lives with proper support services and early treatment. So that individuals with ASD make full use of what they are capable of and particupate in all aspects of life, such as school, work, and community, there is now emphasis placed upon raising awareness, acceptance, and inclusivity in society.

Canadian public health agencies (2022), Biggs and Carter (2016), and Clark et al. (2015) reported that autistic and ADHD children had lower mental health and quality of life compared to typically developing children. Similar results emerged in studies by Jonsson et al. (2017) and Clark et al. (2015). Recreational exercise has positive effects upon mental health, quality of life, and ability to manage adverse life occurrences, as asserted by García-Villamisar and Dattilo (2010) and Hutchinson et al. (2008).

Additionally, children with autism who participated in a diverse group of activities performed better in terms of being emotionally and socially better, as per studies conducted by bohnenrot et al. (2019).

According to Simpson et al. (2018), mothers/fathers of autistic children notice that there is often little participation of children in numerous settings such as home, school, and community.

It remains challenging for autistic children to engage in community recreation due to social and systemic barriers, as per studies by Gregor et al. (2018).

These findings indicate that autistic children require more specialized leisure programs (Gregor et al., 2018; Gray, 2017).

When autistic people gain access to technology, then participation becomes more probable, as per researchers, doctors, and caregivers (Bölte et al., 2010; Frauenberger, 2015; Ghanouni et al., 2020; Scheepmaker et al., 2018).

Per numerous studies (Howorth et al., 2019; Ke et al., 2022; Lorenzo et al., 2019; So et al., 2019), robot-mediated role playing, virtual reality, and augmented reality systems-based interventions implemented improvements upon storytelling skills, upon reading reception, and upon participation. However, studies about how technology can support leisure activity are few. There is reduced social necessity while engaging with technology, such as while in a video game, virtual reality head-mounted display, Smartphone app, or BCI system, due to more structured and predictable interactions. Since technological involvement lowers social tensions and gives structure to interactions, it can promote more human interaction (Frauenberger, 2015). In spite of warnings issued by doctors and caregivers about the potential of becoming too dependent on technology (Ghanouni et al., 2020; Frauenberger, 2015), neurotypical individuals are urged to consider technology with autistic individuals' perspective.

## III. Overview of BCI Technology

Contemporary Human-Computer Interaction technology has developed with the rise of the Brain-Computer Interface (BCI). Brain-computer interfaces (BCIs) also support two kinds of controlled interactions: active BCIs, in which software programs and the human brain itself give direct commands, and passive BCIs, in which humans and machines exchange data to give a comfortable and painless user experience. Brain-computer interfaces (BCIs) will benefit artificial and computational intelligence (AI) and allied domains, as BCIs allow natural brain-machine interaction. Advances in machine learning algorithms and a better understanding of neurobiological mechanisms are among the numerous reasons that contributed to this advancement (Al-Nafjan et al., 2017).

There are over 100 billion nerve cells in a human brain that are accountable for a vast range of complicated executive functions such as reasoning, planning, as well as processing of thoughts (Haider & Fazel-Rezai, 2017). This provides opportunities for hundreds of BCI apps aimed at the masses to access unprecedented pools of brain-based neural activity. Through such apps, one can improve higher integrative functions such as thinking, learning, producing, speech understanding, memory, and emoting. Instead of depending on input by means of the peripheral nervous system, BCIs translate activity that originates in the brain, offering a substitute for natural communication and control. For individuals who are incapable of operating a computer or phone with hand use, such individuals can convert mental processes into commands that a device such as a computer or phone can understand and act upon. Beyond that, a motor imagery BCI can aid in evaluating the patients' mental states that are being registered under the use of an Electroencephalogram (EEG). Based on Yang et al. (2017), individuals will be in a position to take control of their physiological states as well as mental states.

Additionally, experts have explored this persistent neural activity to extract patterns of the brain with the International 10-20 System of accurate electrode placement (Figure 1).

Graimann et al. (2009) included pattern recognition and signal processing as parts of the system that are usually ascribed automatically. The user's scalp can support up to 256 electrodes, facilitating easy and portable signal detection in psychometric or cognitive studies (Ramadan et al., 2015). Aside from replacing traditional control devices such as joysticks and mouse, BCI applications possess a vast variety of potential uses in domains such as painting, home automation, attentional training games, stroke rehabilitation, and lie detection (Finke et al., 2009; Fazel-Rezai and Ahmad, 2011).

Even in healthy individuals or in cases of more moderate movement disorders, BCIs could be of value in communication as well as in rehabilitation of a great number of disorders; however, they are devised primarily to support individuals with extreme motor disability who could not otherwise speak. Brain-computer interfaces (BCIs) could be supported by advances in cognitive neuroscience in a number of domains, such as, but are not limited to: accessibility, attention, fatigue, stimulation, distress, and training tasks (Allison et al., 2007; Allison, 2009). Figure 2 illustrates the generic BCI system introduced by Li et al. (2009) that contains algorithms corresponding to data collecting, pre-processing, feature extraction, and translation.

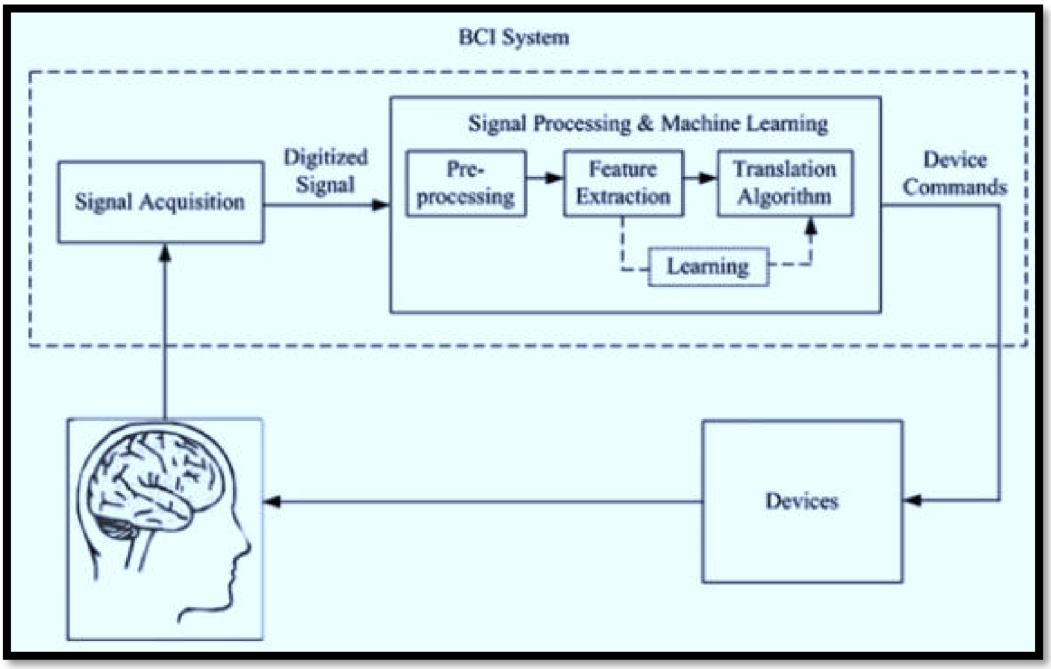


**Figure 1. Basic layout and process of a BCI system**

As Zhu and Bai (2024) postulate, BCI technology is revolutionary in that it facilitates direct interface between the human brain and external devices through decoding neural processes. It predominantly employs techniques such as electroencephalography (EEG) and functional magnetic resonance imaging (FMRI) to monitor and analyze brainwave signals, translating intricate neural impulses into quantifiable commands or data.

## Definition and basic principles

Three components constitute an architecture for a BCI: signal acquisition capability, signal processing capability, and feedback capability. At the signal acquisition stage, noninvasive or weakly invasive neural imaging techniques like functional magnetic resonance imaging (FMRI), electroencephalography (EEG), or other techniques capture raw data about brain activity (Liu, D., Li, Q. 2013). Figure 2 illustrates how the human brain and the device share information via the feedback section, which provides the deciphered information to the outside device. Electroencephalography (EEG) is an indirect technique that records brain waves by using scalp electrodes. FMRI measures differences in brain blood flow, and this enables it to indirectly assess brain activity. Numerous BCIs have utilized these technologies.

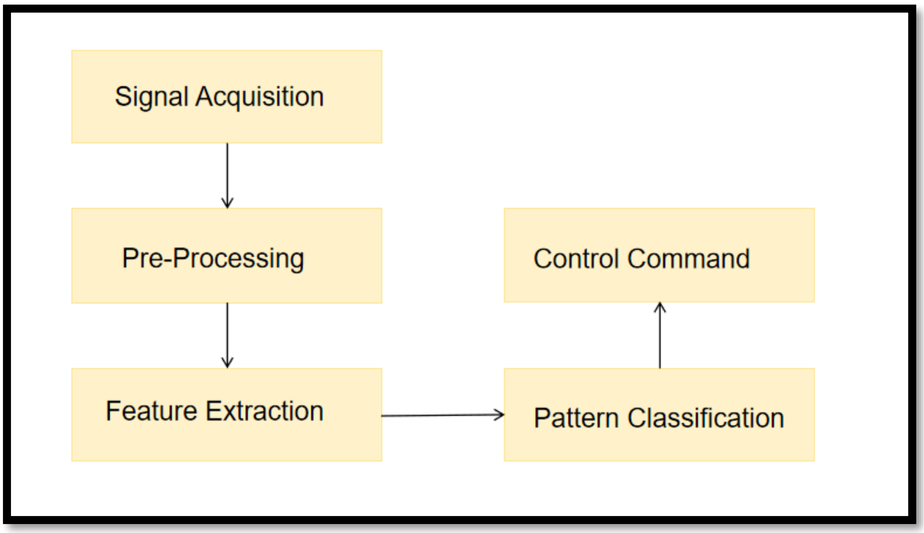


**Figure 2. The architecture of BCI comprises three principal components**

## Classification of BCI

Noninvasive BCIs and invasive BCIs are both acknowledged by Zhang et al. (2024). The advantage of noninvasive BCI is that it involves no invasion of the patient's body whatsoever, but the quality of the signal may be degraded because of using external imaging devices or electrodes on the scalp to measure brain activity. There are surgical risks and ethical issues with invasive BCI, that involves inserting electrodes into the cerebral cortex to access better quality data. Table 1 (Zhao, H. 2009) illustrates that different BCIs are strong in some respects and weak in others in different contexts.

| Non-embedded (noninvasive) BCI | | Embedded (intrusive) BCI | |
|---|---|---|---|
| advantage | disadvantage | advantage | disadvantage |
| High safety: there is no need to implant equipment inside the human body, thus avoiding the risks related to surgery. | Signal quality: Because the signal penetrating the scalp is weak, the signal quality may not be as good as the embedded BCI. | High signal quality: neural activity data with high resolution and accuracy can be obtained. | Surgical risk: It is necessary to perform surgery to implant equipment, which may involve high risks, such as infection or other surgical related complications. |
| Easy to accept: suitable for a wide range of user groups, not limited by individual health or age. | Accuracy limitation: it is impossible to obtain deep or high-resolution neural activity data, so the accuracy is limited in some applications. | Precise control: Higher level control can be achieved, such as precise motion control or complex information transmission. | Adaptability limitation: it may not be suitable for all people, especially those who cannot undergo surgery because of personal health conditions or age restrictions. |
| Convenience: it is relatively convenient to use and does not require long preparation or recovery time. | Limited control ability: unable to realize some advanced functions, such as direct control of prosthetic limbs or complex operations. | Long-term stability: equipment is usually more stable and not easily disturbed by external environment. | Usage restriction: Additional maintenance and management may be required during use, such as regular calibration or equipment adjustment. |

**Table 1. Comparison between non-invasive BCI and invasive BCI**

## IV. Challenges and Future Outlook for BCI Technology Challenges

### Technical challenges

There are a number of technical obstacles to the widespread use of BCI. The first issue is that the quality of the data can be negatively impacted by outside interference in EEG signals. Second, sophisticated algorithms are required for reliable interpretation of brain activity data due to its inherent complexity. The expensive price of high-quality devices prevents their widespread use in settings with low resources, so accessibility and affordability are other important factors to consider when designing BCIs.

### Ethical and privacy considerations

Data security and user privacy are also major concerns with BCI applications. Due to the sensitive nature of the information it contains, safeguarding people's brain activity data is a top priority. Furthermore, it is imperative that patients are informed of their rights and that data utilization is clear; hence, clinical applications must adhere to ethical norms.

### Future directions and clinical application prospects

The future of brain-computer interface technology depends on ongoing innovation. More advanced anti-interference devices are necessary, for instance, to enhance data quality. A more complete picture of brain activity can be obtained by merging EEG with other data types, such as functional magnetic resonance imaging (fMRI), using multimodal data fusion techniques. In addition, BCI has several applications in personalized medicine, which allows for the modification of treatment plans based on unique patient traits. When it comes to autism spectrum disorder (ASD), brain-computer interface (BCI) technology has a lot of potential for improving clinical diagnostic efficiency, tailoring therapy and rehabilitation to each unique patient, and more.

**Tailored diagnostics in ASD**

Commonly used in older autism spectrum disorder (ASD) diagnostic processes is a one-size-fits-all mentality that fails to account for individual differences. Instead, BCI technology can analyze individual brain activity patterns to deliver diagnostic insights tailored to each patient. When doctors examine their patients' EEG patterns in various social situations, they can better identify communication and interaction disorders. This allows for the creation of tailored treatment programs.

**Rehabilitation training and real-time feedback**

Beyond its diagnostic applications, BCI technology has many more potential uses in rehabilitation training. Using BCI, one can get real-time feedback while their EEG activity is being monitored, which can help with behavioral and cognitive approach changes. By evaluating EEG data gathered from participants during discussions and then offering them with cues to boost their degree of social engagement, BCI can improve the efficacy of social skills training (Fang, Y. et al., 2024).

**Tele-health integration**

The fast expanding field of tele-medicine is one potential application of BCIs in the diagnosis and treatment of ASD. Thanks to advancements in remote connectivity, clinicians can now observe EEG patterns in real-time, regardless of their physical proximity to patients. Because of this, they are able to give precise diagnoses and recommendations for individual treatment plans. Particularly helpful for people living in areas with few medical facilities, this function expands the range of healthcare options available to them.

**V. The Application of Bci in the Diagnosis of Asd**

**Neural activity pattern recognition**

According to Zhang et al. (2023), BCI can help with the diagnosis of ASD by exposing the distinct patterns of brain activity linked to each characteristic. Brain activity patterns differ significantly between individuals with ASD and those without the disease, as shown by study. As an example, when individuals with ASD interact with others and converse, their EEG patterns show signs of abnormal synchronization and connectivity. With the use of BCI, we can examine this data on cerebral activity and identify the characteristic EEG patterns of people with ASD, which greatly improves the precision and efficiency of diagnosis (Li, Y. 2021).

### Empirical Case Analysis and Application Prospects

Recent research has shown that electroencephalograms can accurately distinguish between typically developing controls and individuals with autism spectrum disorder. For instance, research has demonstrated distinct abnormalities in the brain activity patterns of individuals with ASD compared to healthy controls while viewing social interaction movies. These unique brain characteristics provide a firm basis for the diagnosis and substantially increase the objectivity and accuracy of autism spectrum disorder diagnoses.

Additionally, BCI technology offers opportunities to enhance social communication for those with ASD. Scientific studies have shown that BCI systems can help autistic youngsters improve their social skills. Patients can enhance their social interaction and communication abilities with the help of BCI devices, which allow patients to communicate themselves through the selection of images or symbols. This is achieved by tapping into specific brain waves, such as the P300 wave. Furthermore, research has looked into BCI technology with the aim of controlling and identifying emotions. These systems can analyze EEG data to figure out how a patient is feeling emotionally, and then they can give them personalized advice on how to control their emotions, so they can cope better with anxiety and mood swings.

### Integration with Traditional Diagnostic Methods

By incorporating BCI technology alongside more conventional assessment tools like clinical exams and questionnaires, the precision of diagnoses can be substantially enhanced. In contrast to more traditional methods, which tend to focus on overt symptoms and behaviors, BCI provides comprehensive data on neural activity. By combining different approaches, a comprehensive and multi-dimensional assessment of a patient's health can be accomplished. For instance, by tracking a patient's brain activity in real-time during clinical observations, BCI devices might help doctors make more precise diagnoses.

### Potential for Early Intervention

Crucially, BCI technology demonstrates potential as a tool for early intervention in ASD. Early screening with BCI identifies potential risk factors for ASD, allowing clinicians to begin therapy before symptoms arrive. Over time, BCI could improve treatment outcomes by detecting abnormal EEG patterns earlier and intervening to stabilize babies' brain activity while they engage in social interactions.

## VI. BCIS in Autism Therapy and Intervention

Brain-computer interfaces (BCIs) are a new and exciting development within the field of intervention and treatment for autism spectrum disorder (ASD). These devices can be used to teach autistic individuals as well as improve their neurological and behavioral capabilities without having to invasively monitor them. There has been limited success with behavioral assessments and treatments for autism spectrum disorder (ASD), but these techniques may not address the issue at hand, which is brain dysfunction. BCIs fill this void by allowing the brain to talk to external devices or software in real-time. They do so by enabling direct observation of brain activity, often using electroencephalography (EEG).

Neurotechnology makes it possible to create specially adapted therapeutic interventions aimed at assisting patients with ASD in surmounting their particular emotional and cognitive difficulties.

One of the therapeutic uses of BCIs for autism is neurofeedback training. By constantly observing and responding to cues sent by their neurons, the patients in this method learn how to control their own brain activity. Findings indicating symptom improvement of anxiety, emotional control, and attention deficit hyperactivity disorder (ADHD) in children and adults with autism are promising. The ability of participants to learn to change brainwave patterns to more normal ranges through multiple sessions can be associated with social behavior and communication improvements. BCIs-based neurofeedback has shown to successfully train individuals with ASD to activate areas of the brain associated with social cognition, sensory integration, and executive function. As a complement to neurofeedback, BCIs have been combined with assistive communication devices to assist non-verbal autistic individuals.

Individuals will be able to control computers and other items simply by exercising their brain activity since these devices can interpret intentional and focused neural signals. Individuals with difficulties in motor control or voice expression can now possibly acquire new means of expression and communication from this. The promise of integrating BCIs with virtual reality (VR), augmented reality (AR), and robots to build interactive, immersive environments for behavioral rehabilitation and teaching social skills is also under discussion. With these multi-modal systems, not only can development be monitored more precisely, but treatment exercises can also be designed to be more engaging. However, much more is needed before autism treatments based on BCIs would be regarded as mature. Among the challenges involved are the following: the need for easy-to-use interfaces; the possibility that autistic individuals' brain signals could be quite different from each other; and the challenge in developing systems that accommodate their unique sensory and cognitive needs.

The bad news is that it is not widely used. The good news is that BCI technology is becoming increasingly cheap and accessible due to the improvement in hardware design, machine learning, and signal processing. As per future studies, BCIs can potentially be at the forefront of customized, non-invasive, and neuroscience-driven treatments for patients with autism spectrum disorder (ASD), possibly revolutionizing the treatment of this condition. Children with ASD and ADHD might gain from a brain-computer interface (BCI) intervention that processes electroencephalogram (EEG) data, based on a study by Sze-Hui Jane Teo et al., (2021).

Twenty children participated in the trial; one of the groups received the intervention and the other was on wait-list.

The intervention lasted for 8 weeks and involved three weekly BCI-based training sessions.

After four weeks, the second group was contacted again. Based on the user's eye and attention, the BCI-based application presented a sequence of tasks aimed at enhancing social cognitive functions.

No one discontinued the study before finishing all 20 training sessions.
No severe side effects were reported.

Mild headache, fatigue, anger, and episodes of self-injury were some of the side effects. All these issues were addressed in the same meeting. Therapists said that with the proper type of support, participants may be able to sustain their motivation and interest. Outcomes on the ADHD rating scale indicated that the intervention group gained more than the waitlist-control group regarding ADHD symptoms; however, there were no significant changes regarding social deficits as rated by the Social Responsiveness Scale (SRS). It seems that the pre-post gains may be maintained, based on the pooled data. Results indicate that the majority of individuals can stand the BCI-based training. Reductions in the ADHD symptoms were also observed to positively influence. To establish whether our training program works, an upcoming large-scale clinical study shall comprise appropriate controls. Chung et al., (2024) reviewed all available studies on educational and behavioral treatments for individuals on the autistic spectrum (ASD). Comprehensive Early Intervention, or Early Intensive Behavioral Intervention (EIBI), is the most highly recognized intervention program that has been proven to have astounding outcomes in improving adaptive behavior and IQ. The ability to acquire learning, memory, and initiating social interactions were all enhanced positively by the naturalistic developmental behavioral intervention. However, more research has to be conducted in order to ascertain its effectiveness.

Enhancing communication and social skills, and alleviating sleeping, eating, and toileting problems were all the result of extensive individualized intervention, which provides specialized treatment for a particular target behavior. The lack of trained professionals has hindered the proliferation of cognitive behavior therapy (CBT), even though it is the better treatment for emotional issues. In parent-mediated intervention (PMI), parents are taught skills to assist their child with challenging behaviors or to improve his functioning. Treatment and education of Autistic and related communication impairments, sensory integration, speech and language pathology, Interventions most commonly used include those working with children, developmental-based, and social storytelling. Still, there remains a scarcity of firm evidence regarding their effectiveness. These findings corroborate that EIBI, PMI, CBT, and the Early Start Denver Model are helpful interventions in the treatment of autism.

Trained professionals should implement the selected intervention in a manner that is specific to each patient.

## VII. The Role of Interdisciplinary Collaboration in Bci for Asd Diagnosis

Collaboration across different disciplines is crucial for the widespread adoption of BCI technology in ASD diagnosis. Critical domains and their contributions to BCI deployment are as follows:

**Neuroscience**

Building cognitive infrastructure relies on research in the field of neuroscience. The development of efficient ways for acquiring and analyzing signals depends on our increasing knowledge of how the brain works and the neuronal activity that occurs within it. Research into animal models of autism spectrum disorder (ASD) can help researchers better understand the function of specific brain circuits, which in turn can inform the design of brain-computer interfaces (BCIs).

**Engineering and Computer Science**

The fields of computer science and engineering must work together to improve BCI hardware and data analysis methodologies. Engineering high-performance EEG devices is essential for ensuring accurate and dependable data collection. Concurrently, algorithm developers are putting in a lot of time and effort to find ways to interpret complicated EEG signals and extract valuable data.

**Clinical Medicine**

Clinical practitioners play a crucial role in the use and validation of BCI technology. For the purpose of diagnosis and therapy, clinical trials enable doctors to evaluate BCI in real-life contexts, identifying and resolving any issues that may emerge. They can monitor the signs of ASD in patients of varying ages and test the technology on them to find out how reliable it is.

**Psychology and Education**

Insights from the domains of education and psychology can bolster the creation of behavioral and cognitive training programs for individuals with ASD. By utilizing BCI technology, educators and psychologists may create training and intervention modules that are more successful. They may, for instance, design interactive systems and games driven by BCIs to aid autistic children's social and language development.

## VIII. Recent Trends and Technological Innovations

### Multimodal and Wearable Neurotechnology

Recent developments in neurotechnology have focused on multimodal BCI systems that combine multiple types of brain data, such as EEG with fNIRS or MEG. The inner workings of the brain can be better understood with the help of these systems.

Wearable BCI devices are also getting more portable, affordable, and user-friendly, opening up new applications outside of hospitals and clinics. In recent times, there has been a surge in the utilization of open-source platforms and integrated headsets for the recording of diverse biosignals in clinical and laboratory settings.

**AI and Machine Learning–Driven Signal Analysis**

The integration of AI and ML is transforming the way BCIs interpret brain inputs. It is critical for current algorithms to be flexible enough to accommodate individual differences and accurately identify patterns in brain activity in order to help identify ASD, as these individuals exhibit a broad range of symptoms. Researchers are putting in a lot of time and effort to develop individualized machine learning models that can improve the accuracy of diagnoses and tailor treatment recommendations.

**Immersive Environments: VR, XR, and Robotics**

By combining BCIs with VR and XR, we can create interactive and immersive experiences that can be used for therapeutic purposes. Users are able to improve their communication, social engagement, and emotional intelligence with the use of these technologies, which employ meticulously designed simulations. Combining robotics with BCIs to offer adaptive behavior training and real-time feedback is another way to make therapy sessions more engaging and interactive, especially for kids with autism spectrum disorder (ASD).

**Non-Invasive Brain Stimulation in Therapy**

Using signal reading, researchers are exploring non-invasive brain stimulation methods such as theta burst stimulation (TBS), transcranial direct current stimulation (tDCS), and transcranial magnetic stimulation (TMS). These approaches, when coupled with BCIs, aim to increase neuroplasticity, which helps individuals with ASD enhance their cognitive and emotional functioning.

**Neurofeedback Training in Neurodiverse Populations**

Neurofeedback using brain-computer interfaces (BCIs) is an effective treatment for autism spectrum disorder. Controlling one's own brain activity can be mastered by keeping tabs on one's EEG data in real-time. Based on the studies, this strategy can help with attention, anxiety, and emotional management. Children on the autism spectrum who exhibit certain patterns, like the suppression of the mu rhythm, tend to exhibit better social conduct and academic success.

**Adaptive VR-BCI Systems for Engagement and Emotion**

Adjustable algorithms that track user interaction, workload, and emotional status are a new addition to interactive sessions such as social gaming and driving simulation. These applications can establish a closed-loop BCI system that takes the user's brain activity as input and reacts in a timely manner to their cognitive and emotional needs, such as altering the level of activity or offering emotional comfort.

The most recent advancements in the technology of BCI have significantly enhanced its usability, intelligence, and application in the diagnosis and treatment of autism. Neurofeedback training, virtual worlds that immerse, AI-driven analytics, and wearable technology are all technologies that can assist individuals with autism spectrum disorder in a more targeted, non-invasive, and neuroscience-driven manner. Spanning the distance between where autism therapy currently stands and where it has the potential to go in the future, BCIs are on the cusp of taking center stage as technology and research continue to progress.

## IX. Conclusion

Among the numerous domains impacted by the neurological illness known as Autism Spectrum illness (ASD) are social interaction, communication, and behavior. Conventional approaches to diagnosing and treating autism spectrum disorder (ASD) have included things like clinical observation, behavioral assessments, and parent-reported questionnaires. These methods, while effective, can be time-consuming, subjective, and miss the neurological dysfunctions at their source. Brain-Computer Interface (BCI) technology has recently arisen as a game-changing tool in this field, providing a more objective, real-time, and neurologically grounded method of diagnosis and intervention. By directly reading brain signals, most often from electroencephalograms (EEGs), brain connectivity interfaces (BCIs) allow for the early and reliable diagnosis of autism spectrum disorder (ASD).

Beyond its diagnostic applications, BCIs are revolutionizing the therapeutic landscape for individuals with ASD. There is promising evidence that some applications, such as neurofeedback training, focus enhancement, mood regulation, and assistive communication technologies, can aid individuals with autism and other co-occurring illnesses in enhancing their social and cognitive abilities. By incorporating BCIs with technologies such as virtual reality (VR), artificial intelligence (AI), and robotics, therapy is taking a more dynamic, interactive, and engaging turn. With these new developments, tailored treatment plans can be created to meet the unique neurological and behavioral needs of autistic individuals.

However, there are still several challenges that need to be overcome before BCIs may be widely used to treat ASD. Signal noise, device usability, cost, and ethical concerns around data privacy and security are among the many technological issues that require fixing. Collaborative efforts spanning neuroscience, engineering, clinical medicine, psychology, and education are essential for ensuring that BCI systems are usable, effective, and supported by clinical trials. Despite these challenges, the outlook for BCI development is positive. Due to the exponential evolution of technology, BCI could one day enable more precise ASD diagnosis and more tailored therapies than was before achievable. An improved understanding, diagnosis, and management of autism spectrum disorder (ASD) might ultimately improve the quality of life for families and individuals affected by the illness.

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