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Emerging Technologies in Diagnosis & Adaptation of Autism Spectrum Disorder

Dr. Maryam Farhang

Associate Professor, Faculty of Health and Social Science, Universidad de Las Américas, Santiago, Chile

Abstract

The incidence of Autism Spectrum Disorder (ASD) has been increasing at an alarming pace, surpassing that of other developmental disorders. Autism is a very heterogeneous disorder -it's rare for individuals with the diagnosis to resemble each other in terms of their symptoms, and the optimal approach for modulating these symptoms is some combination of therapies, educational methods and treatments. There is no known cure for autism. Instead treatment is left to educators and therapists, who must adapt treatment to the specific needs of each individual student. The past 10 to 15 years has seen the application of many new technologies to autism. This article surveys technologies which have been or could be applied to diagnosis and assessment, therapy, social skills, affect and emotion processing, communication, managing problem behavior, and synthesizing data. Finally, the article suggests criteria for understanding the value of future technologies as they apply to the treatment and education of individuals with Autism Spectrum Disorder.

Keywords: *Autism Spectrum Disorder, therapies, educational approaches, treatment, diagnosis, technologies.*

1. Introduction

Autism Spectrum Disorder refers to a neurodevelopmental disability which can be characterized by repetitive patterns of actions along with difficulties in social communication and social interaction. The symptoms most likely become visible in the initial stages of childhood. It starts from around two and three years, and remain for life and also impacts the daily functioning of individuals. According to Centre for Disease Control (CDC) statistics, ADDM Network, the CDC (2010) reports that about 1 out of 68 children have Autism Spectrum Disorder, each with a unique mix of intellectual challenge throughout the wide spectrum, each with varying manifestations, resulting in uneven, unique patterns of development and learning styles [4]. Generally, students are more capable of rote memorization tasks, also can perform mathematical tasks which sometimes requires counting and calculation, but struggle in social settings and in generalizing learning from one situation and setting to another, experiencing anxiety when interacting with other peers, students and adults. Based on these reasons, the given instructions typically require repetition of the same instructional material in different formats, and with limited distractions and presence of other students or adults (Klin, 2000; White, 2007) [16,26]. ASD students are frequently known as "visual learners" (Rao, 2006; Joseph, 2002) [21,12].
benefiting from the presentation of material in visual and pictorial format. Furthermore, a number of studies have shown that

students with ASD both benefit and prefer to use computers in the learning process (Goldsmith, 2004) [9]. Computer-based environments offer predictable, controlled and structured environment that students with ASD prefer. Virtual and Augmented Reality technologies extend this experience by offering a technology-supported learning environment that is integrated with the natural environment, or that simulates natural, every-day situations and interactions in a safe and non-threatening manner.

Traits of Persons with Autism Spectrum Disorder

Neurodevelopmental disorders have a varying impact on individuals. Autism spectrum disorders (ASD) are characterized by affected social interactions or communication difficulties as well as specific behavioral patterns. Indeed, the features seen in ASD range from very subtle social deficits to extreme communication and behavioural issues that result in assessment with two clinical disorders, reflecting the term “spectrum” used. The set of causes for ASD is still not clear but the increasing rates of evidence has indicated that maybe genetics and environmental factors could have a clear contribution to the development of the disorder. People diagnosed with Autism Spectrum Disorder have difficulty in the social elements of reciprocity and social interaction. They also have cognitive and learning traits that require a plan or scheme which is modified to meet specific needs or preferences. But individuals with ASD performs better when it comes to solving puzzles (arrange shapes, objects, or pieces in a specific spatial configuration) and a spatial perceptual and coordination assignment which focuses on tasks that challenge and assess a person’s ability to understand and interact with their environment. They have the ability to perform these tasks much better than others.

Hence, they don’t have any problem understanding ideas or any sort of things in a pictorial format but they may deal with difficulty understanding the same things in a verbal and written language. They are generally competent of recognizing words, applying phonetic aptitudes and knowing word meanings. They also illustrate quality in the region of discourse and dialect, such as sound generation, lexicon or straightforward syntactic structures, but have critical inconvenience keeping up discussion or utilizing discourse for social intelligently purposes. They may perform numerical computations moderately effortlessly, but battle to illuminate complex scientific problems. The variety in cognitive capabilities and learning inclinations result in an assortment of qualities and shortcomings in a student's scholarly execution, social interaction, and in generally behavior.

In light of these varieties of cognitive capabilities and learning inclinations, coupled with the prove that ASD populaces are regularly more outwardly arranged, it has been contended that directions handle ought to be profoundly individualized (Klin, 2000) [16]. Individualized plans ought to consider cohesive environment with student-preferred reinforcers, successful prompts, and tolerable social settings (Klin, 2003) [15]. All these instructional considerations and special educational needs make a compelling case for the applications of immersive, customizable, and natural technologies such as is afforded in augmented and virtual reality environments.

Advances in Diagnostic Methods

Virtual Reality

Virtual Reality is a computer technology that simulates the experience of being in a physical environment by rendering simulated, life-like, interactive environments and situations onto the immersive user interfaces - stereoscopic displays and devices, large-screen computer monitors, or wearable multimedia devices. It is a technology applied in a variety of domains ranging from computer gaming, general entertainment and education (Christou, 2010) [5], to professional and safety training (Van Wyk, 2010; Rizzo, 2006) [25,23], and a variety of therapies (Hoffman, 2004) [10]. In the context of ASD, VR is particularly helpful as it provides opportunities to practice dynamic and real-life social interactions, in which it is used both as an instructional and as a therapeutic aid. A virtual learning world provides learners with ASD with a safer, non-threatening environment for developing skills associated with activities of daily living. Mistakes are less distressing and overall stimuli can be reduced or increased. Environments can be manipulated in simple or more complex formats until generalization occurs. These environments can be selected based on individual needs such as areas of interests, individual level of tolerable input, control of unwanted stimuli, and can be manipulated to be simple or complex based on the individual needs or sensory tolerance of the user.

Emerging Wearable Technology

Other emerging wearable technology includes brain computer interfaces (BCI) or brain machine interfaces (BMI), such as Emotiv EPOC and NeuroSky. The NeuroSky headsets measure brainwave signals and monitors the attention levels of individuals to gain detailed affective information, whereas the Emotiv uses 14 sensors to tune into the electric signals of the brain to detect the user's thoughts, feelings and expressions in real time (Keary & Walsh, 2014) [14]. Smartphones, too, can be used to measure heart rate and affect variability through photoplethysmography (PPG) that can measure subtle changes in skin color as it expands and contracts. This is an example of how wearable technology can collectively become part of our quantified selves – the notion that body data and vital signs can become a kind of an extended memory that provides insights into past and present lives [14]. However, the true potential of all this wearable technology will only be fully realized when human affect and behavior could be automatically analyzed by the systems that deploy this technology. Further, a key element in the long term effectiveness for therapy, education, and training with this technology includes the added critical element of having systems provide feedback and the interventions necessary to deliver personalized instruction and remediation efforts. In this context, the ongoing research and development of an affect-sensitive intelligent tutoring systems is a necessary mediator to accomplish these goals.

Neuroimaging

Neuroimaging techniques have become essential tools in the study of Autism Spectrum Disorder (ASD), offering non-invasive ways to examine both structural and functional changes in the brain. Methods such as functional magnetic resonance imaging (fMRI), structural MRI (sMRI), Diffusion Tensor Imaging (DTI), and Positron Emission Tomography (PET) allow researchers to observe differences in specific brain regions and networks among individuals with ASD.

For instance, fMRI is capable of revealing patterns of brain activity during particular tasks, which helps explain the social, language, and cognitive challenges seen in ASD. DTI focuses on the microstructure of white matter, enabling the study of neural connectivity by mapping bundles of nerve fibers and highlighting connectivity issues. PET scans, meanwhile, can assess the activity of certain neurochemicals, shedding light on the neurochemical basis of ASD.

These advanced neuroimaging approaches not only deepen our understanding of neurodevelopmental abnormalities in ASD but also help identify potential therapeutic targets for more effective interventions. Despite these advances, the complexity of the brain means that understanding ASD fully remains a challenge for future research.

Early Screening Methods

Recently, early screening for ASD has benefited from innovative strategies designed to improve accuracy and convenience. Artificial intelligence (AI) and machine learning are now being used to analyze children's behavioral videos and biomarkers, training algorithms to detect behavioral patterns and physiological signals associated with ASD. This technology aids clinicians and researchers in identifying early signs of ASD.

Another promising development is eye-tracking technology, which evaluates children's social and cognitive development by monitoring their eye movement patterns while viewing images or videos. Studies have shown that children with ASD display different eye movement patterns compared to typically developing children, providing a non-invasive method for early screening.

The application of these state-of-the-art advances not as it were makes strides the effectiveness and availability of early screening, but moreover gives unused points of view for understanding the complexity and person contrasts in ASD. In spite of the fact that these approaches are still in the inquire about and improvement organize, they illustrate the extraordinary potential of utilizing innovative propels to make strides the prepare of ASD screening and conclusion. With advance approval and refinement of these methods, it is anticipated that they will make a critical commitment to the early recognizable proof and intercession of ASD in the future.

Robotics

Collaborative robotics projects are being used to increase socialization for students with ASD, in addition to supporting the learning of STEM concepts (Yuen, Mason, & Gomez, 2014) [27]. Robotic assisted therapy is also being used to improve deficits in social skills and communication for children with ASD (Miskam et al., 2014) [19]. Despite the use of robotics for therapeutic interventions and developmental support is far less prevalent than the use of computer games and virtual stimulations.

Augmented Reality Wearable Systems:

As an educational tool, Augmented Reality (AR) has been shown to have potential in teaching skills within a specific range of areas for students equipped with various capabilities (McMahon, Cihak, Wright and Bell, 2015) [17]. Richard, Billaudeau, Richard and Gaudin (2007) [22] showed evidence that the use of AR with ID elementary students contributed to greater learning outcomes and engagement while learning matching skills. In an effort to develop scaffolded support for individuals with disabilities, AR wearable systems (such as systems that use head-mounted gear) have had the most success in that they support the development of functional skills. For example, training individuals with disabilities how to assemble and disassemble parts on a laser printer (Feiner, Macintryre, & Seligmann, 1993) [8], and aid in the navigation of indoors and outdoors spaces (Höllerer, Feiner, Terauchi, Rashid, and Hallaway, 1999) [11].

Intelligent Tutoring Systems:

Intelligent Tutoring Systems (ITSs) are systems that provide a suite of tech based tools, including use of games and immersive simulations that are affect-sensitive and personally responsive to individuals.

Tutoring system researchers have recognized the need to identify and address affective states that lead to disengagement in learning activities for both normal and autistic populations, particularly when they fall into a frustrated state (Brosnan, Ashwin,Johnson, & Benton, 2012; D'Mello Strain, Olney, & Graesser, 2013) [3,6].

When an individual is in a frustrated state, the range of solutions to address this frustration includes changing the elements in a system that elicits frustration, and supporting the learner in their ability to recover, manage, and persist in their task. Amsel's frustation theory (1992) [1], suggests that achieving goals involves resolving emotional conflicts rather than escaping them. Therefore, to encourage a learner to overcome frustration, while not changing the nature of the system elements, requires finding ways to help the learner recover, manage, and persist through frustration to persist in their learning tasks (Kapoor, Burelson, & Picard, 2007) [13].

McQuiggan, Lee, & Lester (2007) [18] maintain that ITSs should provide support to help students cope with frustration to increase their tolerance of frustrating learning situations. Through diagnosis and detection of the affective state of frustration, ITSs can be configured to enact corrective affective scaffolding strategies, such as specific feedback motivational messages (Robison, McQuiggan and Lester, 2009) [24].

However, just as human-to-human assessment and feedback is a complicated endeavor, selecting interventions to respond effectively to learners in a frustrated state, and provide the best possible feedback, is similarly a complicated process.

D'Mello, Strain, Olney, and Graesser (2013) note that a "one size fits all" approach to affective feedback is unlikely to regulate emotional experiences such as frustration, and that what is needed is an approach that coordinates cognition and emotions that is also adaptive to an individual's knowledge, goals traits, and moods. This is especially important when effective support is being provided for individuals with autism spectrum disorder, who frequently face challenges with social interactions and have limited interest to display distinct cognitive abilities [6].

Acknowledging the diverse abilities and experiences of ASD individuals, the technological advancements and therapy based interventions must be customised to meet the different needs of ASD community through collaborative interdisciplinary approaches, solutions that are customised to individual needs, emotionally sensitive and grounded in practical situations. (Begoli, 2014) [2].

Technology Assisted Intervention

Technology-assisted mediations have gotten to be a vital advancement in the field of ASD treatment in later times, giving modern ways for children with ASD to learn and communicate. Many children with autism spectrum disorder (ASD) benefit from technology-based tools like computers, tablets, smartphone apps, and virtual reality. These resources are designed to boost communication, social skills, and thinking abilities by using interactive games and activities. Since these programs can be tailored to each child's interests and needs, the learning experience feels more engaging and appropriate for their developmental stage.

One big plus is that technology often gives instant, consistent feedback, which helps kids with ASD better understand and process information. Virtual reality, in particular, can recreate social situations, giving children a safe and controlled place to practice interacting and solving problems—something that's often tough in regular classrooms or therapy sessions.
Although these tech-based methods show a lot of promise, researchers are still studying their long-term effects and how to use them most effectively. To get the best results, experts usually recommend combining technology with other types of therapy for a more complete support plan.

Evaluation of ASD Research

This systematic review aims to identify technologies that screen or assess for ASD in 0-12-year-old children, summarizing the current state of the field and suggesting future directions. Building on previous review, this study expands its scope to include a broader age range and a wider range of technologies. Our objectives are threefold:

- Examine the effectiveness of technology-based ASD assessments, including their diagnostic and screening accuracy, as well as user satisfaction.
- Investigate the representativeness of research in this field by analyzing socio-demographic factors among participants.
- Discussing the implications of our findings for the development of the future and implementation of technology based ASD assessment methods.

This review aims to support the development of innovative, effective and accessible assessment tools for ASD by identifying and evaluating emerging technologies used to screen or assess ASD.

2. Discussion

With the prevalence of ASD rising over the past decade, there's a growing demand for novel therapies that address both ASD symptoms and related conditions. Unfortunately, the lack of a definitive cure makes families vulnerable to costly treatments that may not be backed by solid evidence and can sometimes cause harm.
Despite these challenges, there are multiple potential treatments that haven't yet shown clear proof in research but might still be effective for certain individuals, given the diversity and heterogeneity of ASD. This highlights the urgent need for advanced research to draw more reliable conclusions about new therapies and interventions.
A promising direction for future research is the use of biomarkers for diagnosis and patient stratification. Relying on standardized biomarkers—instead of just observable behaviors—could help researchers better understand how different treatments work and which subgroups of patients might benefit most. Although biomarker research is still new, early results are encouraging and could shape the future of ASD treatment.
The following subsections have thematically and chronologically highlighted the vital studies on the application of emerging technologies in supporting ASD-inclusive education:

Augmented Reality for ASD Inclusive Education:

Augmented Reality (AR) technology can be used in ASD-inclusive education to empower individuals with autism with additional information and support them practically. AR tools can provide visual prompts and real-time feedback, helping individuals with ASD navigate new environments and understand social cues. For example, AR-based systems have been developed for interactive learning and emotion recognition.

Robotic Assistants for ASD Inclusive Education

Robotic assistants could potentially be used to help learners with autism in inclusive education. For example, a robotic assistant could be programmed to provide visual and auditory individualized instruction and feedback to learners with autism, help them navigate their environment and interact with their peers, and learn and practice new skills. Pliasa et al. (2019) utilized the Daisy robot as a technological intervention for including children with ASD to investigate the possibility of reduced educational outcomes in non-ASD or adopting negative behaviors of children with disabilities. So the study shows that Robots can deliver individualized instruction, help learners with ASD interact with peers, and support the practice of new skills. Studies have shown that robotic interventions can be more effective than text-based instructions for some learners [20].

Digital and Mobile Applications for Autism Inclusion

Mobile apps offer personalized, interactive learning experiences, real-time feedback, and easy access to educational resources. Research shows that tablet-based applications can support communication and classroom routines for learners with ASD. Findings from various study revealed that the children equipped with the intervention exhibited more classroom and communication routines when compared with the control group and the usage of the application became self- initiated within three months.

Application of Wearable Devices in ASD Inclusive Education

Wearable devices are worn on the body and can be equipped with a variety of sensors and technologies which can serve to monitor the physiological and emotional state of learners with ASD, providing them and teachers with real-time feedback on their arousal levels and helping them to regulate their emotions. For instance, Zheng et al. (2019) developed and evaluated WELI (Wearable Life) across 58 classes in a postsecondary inclusive setting to comprehend the effectiveness of the intervention for learners whom are diagnosed with autism. Many findings indicated high student satisfaction and perceived usefulness concerning Focus and Rewards features [28]. Douglas et al. (2022) compared video-coded data with sensor data using a point-by-point agreement to measure the accuracy of the sensor system in measuring social proximity, inclusion may reduce stigma, allow for social learning, increase social acceptance and improve the social standing of students with ASD. The study results suggest that the sensor system can adequately measure social proximity between children whom are diagnosed with autism and their peers and support teachers and practitioners in making instructional decisions [7].

3. Conclusions

Despite great strides in research on ASD, several major constraints still exist. It is likely that advances in technology, including AI, machine learning and VR will transform the diagnosis, monitoring and treatment of ASDs. These advancements have the potential to produce personalized learning or treatment regimens that are more user-acceptable and effective. VR and AR technologies are beneficial technologies for education of children with ASD, particularly suitable for the teaching of critical social skills. The review presented in this chapter shows that this is an area where the number of tools and applications could be further developed to assist, augment, and even substitute existing educational and social skill development methods. Given that the VR and AR field is experiencing a resurgence of interest and applications, we suggest those interested in capitalizing on the affordances of these new and versatile technologies for ASD populations consider further exploring this burgeoning field as new programs and applications will likely have appeared since the time of this published work. It is anticipated that the versatility and effectiveness of virtual reality gaming and other immersive platforms will prove to be highly effective educational and interventional methodologies when integrated with wearable technologies, creating a more effective suite of tech-based learning that will be limited only by the inventiveness of their makers and the needs of its target populations.

4. Future Directions

Fueled by the popularization of the technology, availability and affordability of the VR and AR devices, and by advances in the realism and capabilities of the algorithms, it is anticipated that the field and applications of the VR and AR as assistive technologies will continue to grow and eventually become the dominant tool for the education of children with Autism. These two technologies will be further refined to provide a suite of options that can be used interchangeably to target learning and skill development depending upon the individual needs of the ASD child. While these technologies are designed to solve issues related to motion sickness and awkwardness, we would anticipate that these solutions will lie in calibrating these systems to include functions which are a smaller part of the devices, external projections, or perhaps even audio resolutions. However, the ultimate success of the use of VR and AR tools with children with ASD will lie within its affordances to offer individualized, tailored instruction that assist in the transfer of content, behavior, and affect-detection skill development from the virtual and augmented world into the physical every day one, increasing the odds that ASD children will find academic and personal success alongside their typically functioning peers.

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