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Technological innovations for assessing motor impairments in autism spectrum disorder

Aditi Gandotra (aditi.gandotra@ppk.elte.hu) - Department of Personality and Health Psychology, Eötvös Loránd University (Budapest, Hungary) and Department of Affective Psychology, Eötvös Loránd University (Budapest, Hungary)
Renata Cserjesi (cserjesi.renata@ppk.elte.hu) - Department of Affective Psychology, Eötvös Loránd University (Budapest, Hungary) and Institute of Psychology, ELTE Eötvös Loránd University (Budapest, Hungary)

Abstract
There is an increasing demand for the identification of biomarkers and symptoms associated with Autism spectrum disorder (ASD) to enable its early detection. Substantial evidence indicates that individuals with ASD often experience motor skills impairments encompassing challenges with gross motor skills, fine motor skills, and gait-related issues. Nevertheless, conventional assessment methods for evaluating these motor skill deficits have proven ineffective for assessing children with ASD for various reasons. In view of this, the present chapter focuses on elucidating the utilization of technology-assisted approaches in the early detection of ASD. Research has demonstrated that wearable devices, video analysis, and sophisticated algorithms can deliver objective measurements, facilitate early intervention, and empower individuals with ASD. These findings highlight that technology possesses the potential to revolutionize the early detection and management of ASD, ultimately improving the quality of life for those affected by the disorder.

Keywords: Technological Innovations; Motor Impairments; Autism Spectrum Disorder; Early Detection; Wearable Devices.

Introduction

Autism spectrum disorder (ASD) is a group of neurodevelopmental disorders characterized by impairments in social communication skills and restricted, repetitive patterns of behavior (American Psychiatric Association, 2013). The global prevalence of ASD has significantly increased, with approximately 1 in 54 children being diagnosed with the disorder (Maenner, 2020). The economic burden associated with caring for children with ASD is substantial, involving diverse expenses like healthcare services, therapy, support for families and the labor contributed by caregivers (Lavelle et al., 2014). As a result, there is a growing emphasis on understanding biomarkers and symptoms of ASD for early detection. Early detection allows for timely intervention, enabling children with ASD to receive appropriate therapies and support during critical developmental stages which in turn can significantly outcomes in areas such as communication, social skill, and cognitive development (Elder et al., 2017). Additionally, the timely detection of ASD empowers parents to seek appropriate professional help and make informed decisions regarding their child's development (Mitchell & Holdt, 2014). It also provides them with an opportunity to access resources, support groups, and education programs tailored to meet their child's needs.

Autism Spectrum Disorder (ASD) and Motor Skills

Recent research has sparked renewed interest in the motor development of young children with ASD, as evidence suggests that motor skill impairments may precede and potentially exacerbate the social-communicative symptoms observed in ASD (Harris, 2017; MacDonald et al., 2014). Children, adolescents, and adults diagnosed with ASD have been observed to display various motor impairments during standard motor assessments, which are typically designed for neurotypical individuals (for review see Gandotra et al., 2020; Garot et al., 2022). These impairments often manifest as poor coordination in tasks involving balance, ball play, agility, and speed. Additionally, studies have identified deficits in gross motor skills, such as running, jumping, ball catching, throwing, ascending stairs, jumping upwards, and balance-related skills like one-board balance, walking heel-to-toe, and hopping on mats (Ament et al., 2015; Mari et al., 2003). Furthermore, motor impairments extend to gait patterns, where individuals with ASD exhibit longer stance phases, shorter steps, altered contact patterns, and differences in cadence, hip, and ankle kinetics (for review see Kindregan et al., 2015). Fine motor skill impairments are also evident, including difficulties in manual dexterity, holding and manipulating small objects, cutting with scissors, dressing skills, hand function during activities of daily living, writing skills, tracing, and prehension movement and planning (Green et al., 2009; Miyahara et al., 1997). Children with ASD have also been found to show delays in hand preference development and show qualitative differences in their performance (Pope et al., 2010). Challenges with imitating sequences of motor movements have been noticed as well (Mostofsky et al., 2006).

Motor Skills Assessment

Considering the motor difficulties exhibited by individuals with ASD, there is a clear need for motor assessments tailored to this population. Currently, the motor assessments of children with ASD relies on standardized instruments such as the the Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2) (Bruininks & Bruininks, 2005), Test of Gross Motor Development 2nd edition (TGMD-2) (Ulrich & Sanford, 2000), the Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992), and the Battelle Developmental Inventory (BDI) (Guidubaldi et al, 1984). However, these tools are not suitable for effectively assessing children with ASD for several reasons (for review see Downs et al., 2020). These assessments often require subjective input from trained professionals, making them prone to bias. Moreover, they are time-consuming and tedious to rate. Additionally, the evaluation process can be tiring for the child. Furthermore, these assessments do not allow for evaluating children's behavior in everyday contexts, limiting their ecological validity. These limitations result in restricted access to these tests, leading to long waiting lists even in affluent countries (Batteh et al., 2023). In view of these challenges, technology assisted motor assessments provide new ways to characterize children's behavior in more natural contexts. Some of these technologies are briefly described below:

Technology assisted motor assessments

Postural Analysis: Children with Autism spectrum disorder (ASD) often experience frequent postural instability (for review see Lim et al., 2017). They exhibit a larger support polygon and take shorter strides which can result in difficulties in maintaining head control sitting and walking (Nobile et al., 2011). Nintendo Wii™ Fit balance board (Nintendo, Kyoto, Japan), is a device that can be utilized to evaluate balance and postural stability. This device features sensors in its four corners and operates at a relatively high sampling frequency of 60 Hz. In a study using the Wii balance board to evaluate the balance and postural stability of individuals with autism spectrum disorder (ASD) found significant differences in postural stability between individuals with ASD and typically developing peers who were matched on age and IQ (Travers et al., 2013).

Motor stereotypies: Three-axis accelerometers and pattern recognition algorithms are commonly employed for the automated detection of body rocking and hand-flapping behaviors. Research (Albinali et al., 2009; Rad et al., 2018) have demonstrated that these pattern recognition algorithms have an average accuracy of approximately 90% in correctly identifying repetitive stereotypical motor movements. This effectiveness has been observed in various settings, including controlled laboratory environments as well as real-life ecological settings like classrooms (Goodwin et al., 2011).

Gait: Individuals with ASD exhibit altered walking patterns with numerous abnormalities such as toe-walking, variable stride length and duration, lack of coordination, abnormal head and trunk positioning, reduced plantar flexion, and increased dorsiflexion (for review see Kindregan et al., 2015). Infrared cameras are commonly employed for gait analysis, with the prevailing system being comprised of eight infrared cameras (Elite System™, Bts® Bioengineering, Milan, Italy). The utilization of multiple cameras enables to continuously track each body part, thereby minimizing occlusion issues. Nobile and colleagues (2011) utilized a system equipped with markers to analyze the walking patterns of children with ASD ($N = 16$) and a control group ($N = 16$) on a 10-meter walkway. The results revealed that children with ASD exhibited significantly shorter step length, wider step width, and marginally slower mean velocity compared to the control group. Furthermore, there was a notable reduction in the range of motion in the hips and knees. Similarly, another study employed automatic motion analyzer consisting of markers and six cameras (Vicon Motion Systems, Oxford, UK) to examine the steps of children with ASD ($N = 11$) and controls ($N = 9$). The findings showed that the steps of children with ASD were generally smaller and slower, there was increased variability in movements of the head, shoulders, and hips compared to the control group (Longuet et al., 2012).

Grasping: Impairments in grasping can be assessed using different kind of technical aids such as infrared cameras, accelerometers, gyroscopes and more complex robotics systems. Additionally, the assessment of grasping abilities can also involve the use of sensors integrated directly into the objects of interest. One example is the work by Campolo and colleagues (2008), who developed a ball embedded with sensors to analyze the grasping patterns of children with ASD. Crippa and colleagues (2017) demonstrated that a three-dimensional infrared camera optoelectronic 60-Hz SMART D system™ (Behavior Tracking System Bioingegneria, Garbagnate Milanese, Italy) could effectively assess simple upper-limb movements. This system utilized markers placed on the wrists and hands of participants. By employing an SVM classifier based on seven features related to the goal-oriented part of the movement, the system successfully classified the movements of low-functioning children with ASD compared to controls. The system achieved an impressive accuracy of 96.7%. Similarly, Campione and colleagues (2016) utilized the same system to demonstrate that children with ASD exhibited a longer duration to complete the entire reaching movement.

Conclusion

The use of technology in the early detection of ASD through the identification of motor abnormalities holds great promise for improving outcome for individuals with ASD. By leveraging wearable devices, video analysis, and advanced algorithms, technology can provide objective measurements, facilitate early intervention, and empower caretakers of those with ASD. Despite the advancements, there are still obstacles to overcome in this field, which include the varying nature of motor abnormalities and ethical concerns related to recruiting participants for research studies. Nonetheless, with continues research and development, technology has the potential to revolutionize the early detection and management of ASD, ultimately enhancing the lives of individuals with ASD.

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