

From Sensation to Interaction: Sensory–Motor Pathways in Autism spectrum Disorder

من الإحساس إلى التفاعل: المسارات الحسية الحركية في اضطراب طيف التوحد

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Abstract:

المخلص:

This study examines the relationship between sensorimotor integration and social interaction in children with Autism Spectrum Disorder (ASD). It aims to highlight the theoretical foundations explaining how sensory processing and motor skills support communication and social engagement.

A descriptive-analytical approach was adopted through a review of the relevant literature on ASD, sensory integration theory and neurodevelopmental.

The findings suggest that atypical sensory processing and motor difficulties negatively affect social interaction and communication in children with ASD.

Keywords: Autism spectrum Disorder, sensory–motor integration, social interaction, communication, motor skills.

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تهدف هذه الدراسة إلى استعراض العلاقة بين التكامل الحسي الحركي والتفاعل الاجتماعي لدى الأطفال ذوي اضطراب طيف التوحد، مع إبراز الأسس النظرية التي تفسر دور المعالجة الحسية والمهارات الحركية في دعم التواصل والتفاعل الاجتماعي.

اعتمدت الدراسة المنهج الوصفي التحليلي من خلال مراجعة وتحليل الأدبيات العلمية المتعلقة باضطراب طيف التوحد، نظرية التكامل الحسي والمنظورات التنموية العصبية.

أظهرت النتائج أن اضطرابات المعالجة الحسية والصعوبات الحركية تؤثر سلباً في التواصل والتفاعل الاجتماعي لدى الأطفال ذوي اضطراب طيف التوحد.

الكلمات المفتاحية: اضطراب طيف التوحد، التكامل الحسي الحركي، التفاعل الاجتماعي، التواصل، المهارات الحركية.

1- Introduction

Autism Spectrum Disorder (ASD) is a condition that affects the development of the brain and is marked by a constant shortage of abilities in social communication and interaction, together with behavioral patterns that are restricted in variety and repeated. In addition to these main characteristics, people on the spectrum usually have problems with handling sensory information and coordinating their movements which can drastically affect their living, working and especially their social life as well.

The latest studies point out that the sensory-motor pathways are the main thing that helps to have a social interaction. Sensory activities are the ones that inform the person or animal about the state to which he/she has to direct his/her attention, what is the corresponding emotional reaction and what kind of evaluation he/she has the ability to make and how to respond to the social cues. Motor skills, including both fine and gross motor coordination are the basis for non-verbal communication like gestures, imitation and joint attention which are all very important for having a meaningful social interaction.

The knowledge of the relationship between the processing of sensory inputs and the development of motor skills is of great importance for the creation of effective treatment modalities. The combination of sensory-motor activities into the therapeutic programs has already been proven to be very effective in the communication, adaptive behavior and social participation of children with ASD.

The focus of this article is on analyzing the role of sensory–motor pathways in social interaction in case of autism, giving a comprehensive picture of theoretical frameworks supporting this linkage and presenting intervention methods that utilize these pathways for better communication outcomes. The article is aimed at unraveling the influencing factors of sensory and motor processes on social behavior in ASD children by integrating findings from developmental psychology, neuropsychological inquiries and sensory integration theory.

Despite the growing interest in social communication difficulties among children with ASD, many studies continue to examine communication deficits independently from sensory and motor functioning. However, recent theoretical and clinical evidence suggests that sensory processing and motor coordination play a crucial role in shaping social interaction and communicative behavior.

The current study addresses the following central research problem:

How do sensory–motor pathways influence social interaction and communication in children with Autism Spectrum Disorder?

Based on this problem, the study attempts to answer the following research questions:

- What is the relationship between sensory processing difficulties and social communication impairments in children with ASD?;
- How do motor coordination deficits affect non-verbal communication and social participation?;
- What theoretical frameworks explain the relationship between sensory–motor functioning and social interaction in ASD?;
- To what extent do sensory–motor interventions contribute to improving communication and adaptive behavior in children with ASD?;
- What are the major limitations and challenges facing sensory–motor intervention approaches in ASD research and practice?.

2- Research Hypotheses

Although the present article is theoretical in nature, it is guided by the following hypotheses derived from the reviewed literature:

- Sensory processing abnormalities significantly contribute to difficulties in social communication and interaction among children with ASD;
- Motor coordination impairments negatively influence non-verbal communication skills such as imitation, gestures and joint attention;
- Sensory–motor integration constitutes a foundational mechanism underlying social engagement and adaptive behavior;
- Sensory–motor-based interventions positively influence communication, emotional regulation and social participation in children with ASD;
- Integrating sensory and motor dimensions within therapeutic programs leads to more comprehensive developmental outcomes compared to approaches focusing exclusively on language or behavior.

3- Objectives of the Study

The present study aims to:

- Examine the role of sensory–motor pathways in shaping social interaction among children with ASD;
- Analyze the relationship between sensory processing difficulties and communication impairments;
- Explore the impact of motor coordination deficits on adaptive and social functioning;
- Present the major theoretical perspectives explaining sensory–motor functioning in ASD;
- Review intervention approaches based on sensory–motor integration;
- Highlight the practical implications of sensory–motor interventions for clinicians, therapists and educators;
- Identify current research limitations and propose future directions for investigation.

4- Significance of the Study

The significance of the current study emerges from both theoretical and practical perspectives.

4-1-Theoretical Significance

The study contributes to the growing body of literature emphasizing the interconnectedness of sensory, motor and social dimensions in ASD. It expands the understanding of communication difficulties beyond traditional language-centered interpretations by presenting communication as an embodied and sensory–motor process. Furthermore, the study synthesizes multiple theoretical frameworks, including sensory integration theory, neurodevelopmental perspectives and embodied cognition.

4-2-Practical Significance

Practically, the study highlights the importance of integrating sensory–motor activities into intervention programs designed for children with ASD. The findings may assist occupational therapists, speech therapists, psychologists and educators in designing more comprehensive and individualized therapeutic approaches. In addition, the study may guide future intervention programs aimed at improving communication, adaptive functioning and social participation.

5-Definitions of Key Concepts

Autism Spectrum Disorder (ASD):

Autism Spectrum Disorder refers to a neurodevelopmental condition characterized by persistent deficits in social communication and social interaction, accompanied by restricted and repetitive patterns of behavior, interests or activities (American Psychiatric Association, 2013).

- Sensory–Motor Integration:

Sensory–motor integration refers to the neurological process through which sensory information received from the environment and the body is organized and transformed into purposeful motor and behavioral responses.

- Social Interaction:

Social interaction refers to the reciprocal exchange of verbal and non-verbal behaviors between individuals within social contexts, including eye contact, gestures, imitation, emotional responsiveness and joint attention.

- Motor Coordination:

Motor coordination refers to the ability to execute smooth, organized and purposeful body movements involving fine and gross motor skills.

- Sensory Processing:

Sensory processing refers to the manner in which the nervous system receives, organizes and responds to sensory stimuli from the environment, including tactile, auditory, visual, vestibular and proprioceptive inputs.

6- Literature Review

Research concerning sensory–motor functioning in ASD has increased substantially over the past two decades. Previous studies consistently demonstrate that sensory abnormalities and motor impairments are strongly associated with communication and social difficulties.

Baranek (2002) examined the effectiveness of sensory and motor interventions for children with ASD and reported that sensory abnormalities significantly affect social participation and adaptive functioning. The study emphasized that sensory-based interventions may improve engagement and responsiveness during interaction.

Fournier et al. (2010) conducted a meta-analysis investigating motor coordination in individuals with ASD. The findings revealed substantial

impairments in both fine and gross motor skills among children with autism compared to typically developing peers. The researchers concluded that motor deficits constitute an important characteristic of ASD and may influence imitation and social participation.

Mosconi et al. (2015) explored neurobehavioral abnormalities in ASD using functional imaging and electrophysiological evidence, Their findings demonstrated atypical neural connectivity affecting sensorimotor functioning, motor planning and social responsiveness.

Schaaf et al. (2014) carried out a randomized controlled trial examining the effectiveness of sensory integration therapy in children with ASD. Results indicated significant improvements in goal attainment, emotional regulation and social responsiveness among children receiving sensory integration intervention.

Tomchek and Koenig (2016) highlighted the importance of occupational therapy approaches addressing sensory processing and adaptive behavior. Their work emphasized individualized intervention planning based on comprehensive sensory and motor assessments.

Despite these contributions, existing literature still demonstrates several limitations. Many studies rely on small samples, differ considerably in intervention protocols and employ subjective outcome measures. Furthermore, limited research integrates sensory, motor and social variables simultaneously within unified theoretical models.

7 - Theoretical Foundations

A comprehensive understanding of the influence that sensory–motor pathways have on autism will depend on the applicable theories from different schools of thought such as sensory integration theory, neurodevelopmental perspectives and embodied cognition. The three mentioned theories offer insights into the interplay between sensory inputs, motor skills and social interaction.

7-1 - Sensory Integration Theory

The Sensory Integration (SI) theory, or the theory of sensory integration, formulated by Ayres (2005) argues that the ability of the brain to organize and make sense of sensory data is the key to the successful interaction with the environment. Generally, children with autism spectrum disorder (ASD) show either extreme sensitivity (hyper-sensitivity) or no sensitivity (hypo-sensitivity) to one or more of the senses. This usually

results in difficulties in concentrating, controlling their emotions and participating in social activities. The SI theory claims that the application of properly selected sensory experiences can improve the brain's ability to process sensory inputs and respond adaptively to them, thus indirectly supporting functional behavior and social communication.

7-2-Neurodevelopmental Perspectives

Neurodevelopmental studies point out that non-typical brain connectivity and processing occur in those with ASD, which has an impact on both motor planning and sensory perception (Mosconi et al., 2015). It is possible that the malfunction of the sensor motor networks is responsible for the difficulty in imitation, gesturing and joint attention which are used as social communication skills. When the neural mechanisms are understood, one is able to see the rationale behind broadening the scope of social and communicative functioning when using the interventions that target sensory–motor pathways.

7-3- Embodied Cognition and Social Interaction

The exaggerated physical experience of the cognition framework treats cognitive processes, including social understanding, as totally physiological (Gallese & Sinigaglia, 2011). In the case of autism, the unskilled motor activities may hinder the imitation of others' movements or even drawing meaning from gestures, thus, creating non-reciprocity issues in the social arena. Therefore, the linking up of bodily actions with social meaning can be through the facilitation of social cognitive development owing to the integration of sensory and motor experiences through therapeutic activities.

The blending of these theoretical perspectives thus highlights the paramount importance of sensory–motor processing in the case of social interactions with autism. They explain the necessity of interventions that consist of combining sensory experiences with motor activities in order to enhance communication, emotional regulation and social engagement.

8- Sensory–Motor Processing in Autism

Differences in sensory-motor processing are a major characteristic of Autism Spectrum Disorder (ASD), which not only influences daily activities but also social communication to a great extent. Studies show that the children with ASD who had unusual sensory experiences and motor coordination problems got less help in their developing adaptive behaviors and social participation (Baranek, 2002; Tomchek & Koenig, 2016).

➤ Sensory Modalities Affected ASD children often have hyper- or hypo-responsiveness in different sensory areas such as:

- Tactile: Being over- or under-sensitive to touch may lead to problems in performing such activities as grooming or handling objects.
- Vestibular: People with ASD may have problems with perceiving their body movements and may develop improper postures and uncoordinated movements as a result.
- Proprioceptive: Children who struggle with aware of their body in space might resort to making awkward or imprecise movements.
- Auditory and Visual: Sensory issues might cause the child to be easily distracted or annoyed in loud or visually complicated places (Baranek, 2002).

➤ Motor Challenges Motor deficits are frequently present in children with Autism Spectrum Disorder (ASD) and they show up in different forms:

- Fine motor skills: Impairments in handwriting and grasping.
- Gross motor skills: Difficulties in running, jumping or coordinating large body movements.
- Motor planning and praxis: Difficulty in sequencing and executing new movements can hinder imitation and playing (Fournier et al., 2010).

➤ Impact on Daily Functioning and Social Engagement Sensory and motor differences cause social interaction issues in several ways:

- Children who are not good at playing will also not have the chance to be with their peers.
- Difficulties in gesture imitation or signaling through non-verbal cues can lead to communication break-downs.
- Over-sensitive to certain stimuli might result in the child withdrawing, becoming anxious or disruptive in the social setting (Tomchek & Koenig, 2016).

It is necessary to comprehend these sensory–motor challenges for the creation of interventions that not only aim at perception and action but also help in social communication and adaptive functioning.

9- Sensory–Motor Pathways to Interaction

Sensory–motor pathways are indispensable for conversing through sensory input and motor skills. However, the case of children suffering from

Autism Spectrum Disorder (ASD) illustrates how differences in pathways can result in a disruption of attention, emotional regulation and non-verbal communication which are all key factors to social engagement (Baranek, 2002, Schaaf et al., 2014).

9-1- From Sensory Input to Social Response

Sensory experiences and children more or less adjusted to them, affect their interpretation of social cues and potential reactions to them, positively or negatively. For example, someone who is very sensitive to sound or touch might become less socially interactive or even anxious, whereas someone who does not hear or feel that much might not even notice the social signals (Tomchek & Koenig, 2016). Therefore, the successful processing of sensory information is the very first step to social partners' attending, gestures' interpreting and responding in social situations in a proper manner.

9-2- Motor Skills as a Bridge to Communication

Motor skills are the basis for the modes of expression that are non-verbal, such as gestures, facial expressions, and imitation, all of which are able to retain and keep the conversation going. Motor planning and coordination also make it possible for children to engage in joint attention and shared activities, which are the very elements of social reciprocity (Fournier et al., 2010). Thus, motor skills will not be the only area of children's development affected when they get autistic spectrum disorder; rather, it will also be the area of non-verbal communication that they will become stronger in.

9-3- Illustrative Scenarios

Imagine a child who has trouble with proprioceptive awareness and fine motor coordination. This child might find it hard to join in group play which can cause a decrease in social interaction. Sensory-motor interventions like tactile activities and guided imitation exercises can improve fine motor skills and involvement, thus helping to create a bond between peers. The same goes for vestibular and balance activities, which can enhance posture control, hence allowing smoother interaction in active social environments (Ayres, 2005).

Sensory–motor pathways, which connect sensory perception to motor action, are the biological and behavioral basis for social interaction. It is necessary to comprehend these pathways in order to create interventions that

effectively support communication and social participation in children with ASD.

10- Intervention Approaches

Interventions are specially designed to deal with sensory–motor processing can turn around children with Autism Spectrum Disorder (ASD) in terms of their social communication and normal functioning. These techniques are all about the development of sensory integration, motor coordination and sensory experiences' adaptiveness through social behaviors.

10-1- Sensory–Motor-Based Therapies

Occupational therapy, above all, which includes sensory integration (SI) therapy is the main method to treat sensory processing deficiencies in ASD. SI therapy consists of a series of activities that provide a specific kind of sensory input, which in turn aids the brain's ability to organize and react properly (Ayres, 2005). Similarly, physiotherapy and play-based approaches gradually work on motor coordination, balance and postural control which are the essentials for toddler's socializing and participating (Schaaf et al., 2014).

10-2- Evidence of Effectiveness

Studies indicate that sensory–motor-based interventions have a positive impact on communication, adaptive behavior and social engagement. One such research is that of Schaaf et al. (2014), which showed that children receiving SI therapy had social responsiveness and daily functioning significantly improved. Moreover, integrated motor skill programs have been a factor in the enhancement of imitation, joint attention and gesture use, which all contribute to social reciprocity (Fournier et al., 2010).

10-3- Guidelines for Practitioners

Interventions that are effective should be tailored to the particulars of each case, and also should be based on thorough assessments of both sensory and motor capabilities. The recommendations for the practitioners are the following:

- The identification of particular sensory sensitivities and difficulties with motor skills;
- The planning of the structured activities that will give graded sensory experiences;

- The blending of motor skill training with social and playful activities;
- The keeping of progress charts and the changing of interventions according to the child's responsiveness (Tomchek & Koenig, 2016).

Interventions can thus link up sensation with social interaction through the integration of sensory experiences and motor skill development. Children's functional abilities will be enhanced by using such approaches and also their meaningful participation and communication will be developed, particularly in the case of children with ASD.

11-Results and discussion

The findings presented in this review highlight the central role of sensory–motor pathways in shaping communication and social interaction in children with Autism Spectrum Disorder (ASD). Across the examined literature, atypical sensory processing and motor coordination difficulties were consistently associated with impairments in joint attention, imitation, emotional regulation and adaptive social participation (Baranek, 2002, Fournier et al., 2010, Tomchek & Koenig, 2016). These findings support the assumption that communication difficulties in ASD cannot be explained solely by language deficits but rather emerge from complex interactions between sensory perception, motor planning and social cognition.

Research indicates that sensory abnormalities are highly prevalent among individuals with ASD. According to the Centers for Disease Control and Prevention, Autism Spectrum Disorder affects approximately 1 in 36 children, and sensory processing difficulties are reported in more than 90% of diagnosed cases (CDC, 2023). Furthermore, motor impairments such as postural instability, poor coordination and praxis deficits are frequently observed during early childhood and may appear before the emergence of clear social symptoms (Fournier et al., 2010). These statistics reinforce the importance of considering sensory–motor functioning as a core dimension of autism rather than a secondary characteristic.

The theoretical frameworks discussed in this article collectively emphasize that social interaction depends on the effective integration of sensory input and motor output. Sensory Integration Theory explains how difficulties in organizing sensory stimuli may interfere with attention, behavioral regulation and engagement with the environment (Ayres, 2005). Neurodevelopmental perspectives further suggest that atypical neural connectivity within sensor motor networks contributes to difficulties in

imitation, gesture production and reciprocal interaction (Mosconi et al., 2015). Similarly, the embodied cognition approach proposes that social understanding is grounded in bodily experiences and action-based representations (Gallese & Sinigaglia, 2011). Together, these perspectives provide a multidimensional explanation of communication difficulties in ASD.

The reviewed intervention studies also demonstrate that sensory–motor-based therapies can positively influence communication and social functioning. Schaaf et al. (2014) found that children who participated in structured sensory integration interventions showed improvements in social responsiveness, adaptive behavior and participation in daily activities. Likewise, motor-oriented interventions targeting balance, imitation and coordination were associated with enhanced non-verbal communication skills and increased peer interaction (Fournier et al., 2010). These findings suggest that sensory–motor interventions may facilitate communication not only indirectly through behavioral regulation but also directly through the improvement of gesture use, body awareness and interactional synchrony.

In addition, the discussion of sensory–motor pathways highlights the importance of early identification and intervention. Since sensory and motor atypicalities may appear during infancy or early childhood, they could serve as early indicators for developmental risk and allow earlier therapeutic support. Integrating sensory–motor activities into educational and clinical programs may therefore contribute to improving developmental outcomes and social participation over time.

From a practical perspective, the results support the implementation of multidisciplinary intervention models combining occupational therapy, physiotherapy, speech and language therapy and play-based approaches. Such integrated programs may better address the interconnected sensory, motor and communicative needs of children with ASD. Future research should continue exploring individualized intervention protocols, long-term therapeutic outcomes and technology-assisted sensory–motor programs designed to enhance engagement and adaptive functioning.

- Limitations

This review presents several limitations that should be acknowledged:

- The studies discussed relied on heterogeneous samples differing in age, severity of Autism Spectrum Disorder, cognitive functioning and associated developmental conditions. Most intervention studies focused primarily on

children between early childhood and middle childhood, limiting the generalizability of findings to adolescents and adults with ASD.

- Many of the reviewed studies involved relatively small sample sizes, which may reduce the statistical power and reliability of conclusions. Variations in intervention duration, therapeutic intensity and assessment methods also make direct comparison between studies difficult. In addition, several studies depended on parent reports or clinician observations rather than standardized objective measures of sensory–motor functioning and social interaction.

- The target population of the reviewed literature mainly included children diagnosed with Autism Spectrum Disorder who demonstrated sensory processing abnormalities and motor coordination difficulties. However, the degree of sensory and motor impairment varied considerably across participants, reflecting the heterogeneity of ASD itself. Therefore, the effectiveness of sensory–motor interventions may differ according to individual developmental profiles and support needs.

Finally, despite increasing interest in sensory–motor approaches, there remains a lack of longitudinal and large-scale controlled studies examining long-term outcomes. Future research should include more diverse populations, standardized assessment tools and rigorous experimental designs to strengthen evidence regarding the role of sensory–motor pathways in social communication and interaction in ASD.

- Conclusion

The pathways of sensory and motor systems are the main factors that determine the methods of interaction and communication of children with Autism Spectrum Disorder (ASD). Children with ASD often experience processing of sensations differently and have motor coordination problems which may cause them to be less attentive have poorer emotional control and be less able to communicate non-verbally, hence limiting their social interactions. Several theoretical frameworks such as those of sensory integration, neurodevelopmental perspectives and embodied cognition, acknowledge and emphasize the link between sensation, motor control and social behavior. The results of intervention studies have shown that sensory–motor therapies tailored to the individual child can significantly improve their communication, adaptive behavior and social participation.

Combining sensory and motor methods in clinical practice may become a powerful tool to help the developmental and social needs of children with ASD.

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