Sensory Processing Disorder and Its Effect on Children's Skills and Development in Autism Disorders, Attention Deficit Hyperactivity Disorder and Learning Disabilities: A Review Article

Navid Mirzakhani [a], **Saeedeh Shahriyarpour** [a*]

a Student Research committee, Department of Occupation Therapy, School of Rehabilitation, Shahid Beheshti University of Medical Science, Tehran, Iran

Corresponding Author: Saeedeh Shahriyarpour, Student Research committee, Department of Occupation Therapy, School of Rehabilitation, Shahid Beheshti University of Medical Science, Tehran, Iran, ***E-mail***: sshahriarpour2013@gmail.com

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Abstract

Introduction: Sensory processing is an important stage in performance during which the organization and interpretation of received messages is done, and finally the final decision is made. Development in an efficient sensory-perceptual-motor processing system plays an essential role in the successful execution of a task and learning, and a defect in skills may be related to one of the sensory systems and lead to functional problems. The aim of this study was to review the studies related to Sensory Processing Disorder in autism disorders, attention deficit hyperactivity disorder and learning disabilities. **Methods and Materials**: Using keywords (sensory processing disorder, Autism Spectrum Disorder, Attention Deficiency Hyperactivity Disorder, Developmental Coordination Disorder, Learning Disability), articles were searched in Elsevier, Science Direct and Google Scholar databases between 2000 and 2020. **Results**: According to an inclusion and exclusion criterion, 41 articles focusing on sensory processing disorder in autism spectrum disorders, attention deficit hyperactivity disorder, developmental coordination disorder and learning disorder were examined. This disorder is caused by damage to areas of the brain, including the white matter, and Sensory Modulation Disorder (SMD**)** is the most common type. In these people, usually, skills deficits make it difficult for the child to play the role, and the most common interventions among them are based on sensory integration. **Conclusion**: Among the four groups, sensory processing disorder is very common and can be the cause of many problems in their perceptual, motor, behavioral and academic skills.

Key words: Autism Spectrum Disorder, Attention Deficient Hyperactivity Disorder, Developmental Coordination Disorder, Learning Disability, Sensory Processing Disorder

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Introduction

Sensory processing is as one of the most important steps in function and means recording, regulating and organizing sensory inputs and as a kind of brain process that occurs in all organisms (1). Initially, a stimulus is presented to the sensory receptors and stimulates them called message receipting or decoding. After stimulation, the message is transmitted to the brain during the input process, and after reaching the brain, the process of organization and integration occurs. Eventually, the combination of new and previous information leads to the interpretation of data and the final decision, and decisions are transmitted to the organs by the efferent nerves, which form the output process in the form of verbal expression (such as writing) or motor reaction (such as running). If the answer is correct, information will be saved for subsequent periods. If the answer is incorrect a replacement answer is provided. If the person also fails to provide a corrective answer, he/she will inevitably give up (2). Therefore, receiving physical stimuli, transmitting them in the form of nerve impulse, and conscious experience of sensation are necessary for effective comprehension and function, and perceptual-motor activities also play an essential role in the learning process (2, 3).

Defect in skills such as perceptual-motor and motor may be related to one of the sensory systems and have a negative impact on a person's developmental, behavioral, emotional, motor and cognitive abilities. It is called sensory processing disorder (SPD) divided into three groups: sensory modulation disorder, sensory-based motor disorder, and sensory discrimination disorder.(3). Its prevalence is about 40-80% for children with neurodevelopmental disorders, 60-95% for children with autism and 2.8-6.5 % for children without disorders (4). Sensory modulation disorder is a defect in the regulation of the degree, intensity, and type of response to sensory input that can be seen in three forms: sensory over-responsibility, sensory under responsibility, and sensory seeking. Sensory-based motor disorder occurs when a person's physical condition and voluntary movements are inadequate and there is a defect in motor-planning, praxia, sequence, smoothness and control of movements, and is seen in two forms: postural dysfunction and dyspraxia. Sensory discrimination disorder is also related to sensory processing patterns that affect the quality of sensory inputs, especially temporal and spatial features, and the ability to detect their differences and similarities (5).

There is no uniform framework for diagnosing the SPD. Since it cannot be measured directly, caregivers are asked to rate sensory processing-related behaviors. One of the most common tests in this field is Sensory Profile (SP), which evaluates sensory processing patterns, sensory, behavioral, and school components in 4 parts, and 5 versions include infants, toddlers, children, school, and short. It is correlated with other tests such as Sensory Processing Measurement (1, 6). This disorder affects the way information interpreted in the brain and causes inappropriate attention, emotional and motor responses (7). There are also five functional deficits in various areas of occupation, including play, social participation, activities of daily living, instrumental activities of daily living, rest and sleep, and education, which are: reduced social participation and involvement in activities, reduction in length, repetition and complexity of adaptive responses, impaired self-confidence, weakness in daily life skills, and developmental limitations in fine, gross, and sensory-motor skills (4, 8). However it is still unknown that children with Sensory-oriented problems have a real disorder in the sensory pathways of the brain or these defects are associated with developmental and behavioral disorders (6).

Thus, the process of sensory processing has a significant impact on the growth and function of individuals, and the disorder in it negatively affects the perceptual, perceptual-motor gross and fine motor, cognitive, linguistic, social and behavioral skills. As a result, the child is clearly at a lower level than people of the same age and without disorder, thereby making child difficult to play his/her role at home, school and in the community. Due to the fundamental sensory capabilities, SPD may be the cause of some remaining problems after the intervention. Despite the similarity of the results of many studies in this area, due to low samples and not finding a strong reason for sensory and motor problems, conducting more research and finding a connection between sensory processing and other competencies in different groups of clients is emphasized with more examples of people, because understanding this connection can provide a more complete cure. On the other hand, the number of researches in the field of sensory processing, its disorders and sensory- based therapies is high, and the presentation of a review article helps to collect existing information and their results, considering that a new review articles has not been carried out in this area.

Methods and Materials

In this regard, using the keywords: "sensory processing disorder, Autism Spectrum Disorder, Attention Deficient Hyperactivity Disorder, Developmental Coordination Disorder, Learning Disability" in Scopus, Science Direct and Google Scholar databases in the period 2000 to 2020, number of articles were obtained. After studying their summery, 41 articles were selected and evaluated according to the inclusion and exclusion criteria. Given the wide range of research, it has been observed that from 2000 onwards, researchers used the Sensory Profile test for surveying sensory processing, its disorders, and the effectiveness of sensory interventions, which included new results. Therefore, the period of 2000-2020 was selected. Among the studies, original articles and pilot studies with infant or child samples (up to 12 years old) with sensory processing disorder, Autism Spectrum disorder, Attention- Deficit hyperactivity disorder, developmental coordination disorder, and learning disability were selected. Studies that were review article and also studies that samples were more than 12 years old and had comorbidities such as seizure, blindness and low vision, deafness and hearing loss, and heart disease were excluded. Then, the studies were classified according to the subject into 6 different groups: sensory processing disorder, sensory modulation disorder, sensory processing disorder in pervasive developmental disorder, sensory processing disorder in attention deficit-hyperactivity disorder, sensory processing disorder in developmental coordination disorder, and sensory processing disorder in learning disability. The summary of results is shown in the Table 1.

Table 1. The summary of results of included studies

Article Title	Number of group articles	The overall result of the articles
Sensory processing disorder	5 articles (5 original articles)	SPD affects social participation in which the use of sensory diet in combination with listening therapy has a positive effect, and encephalography measurement, sensory gate function, and diffusion tensor imaging are among its diagnostic methods (9-13).
Sensory modulation disorder	5(4 articles original articles and 1 pilot-study article)	The presence of SMD negatively affects social participation and skills, which is one of the priorities of families in treatment with sensory integration interventions, social interaction and adaptation and the child's performance can be improved (14-18).
Sensory processing disorder in pervasive developmental disorder	8 (7 articles original articles and 1 pilot-study article)	Following ASD, the white matter suffers from structural defects that lead to SPD and cognitive problems. As a result, motor and social skills are negatively affected and require intervention. Sensory therapies alone or in combination with other methods such as play and movement, improve goal attainment scale score, autistic behaviors and social skills (19-26).
Sensory processing disorder in Attention Deficit Hyperactivity Disorder	9 articles (8 original articles and 1 pilot-study article)	ADHD in children, along with SPD, usually leads to excessive movement and impaired attention, planning, and social interaction. Hypersensitivity in these children can affect the levels of their endocrine hormone secretion and lead to sensory avoiding behaviors. Behavioral and psychological problems such as anxiety are seen especially in the group of attention deficit disorders along with disturbances in recreational activities and visual perception. Deep input such as heavy vest is an effective intervention in them (27-35).
Sensory processing disorder in developmental coordination disorder	4 articles (4 original articles)	SPD is more common in ADHD and DCD presence with each other, which has a neurological cause and leads to social problems. The association of LD with DCD also has a negative effect on the acquisition of motor patterns and perceptual-motor skills which causes poor balance and stability of the position. These people rely more on feedback in movement and are not able to predict (36-39).
Sensory processing disorder in learning disability	10 articles (10 original articles)	LD children have difficulty in filtering and processing the sensory information, which reduces their praxia and self-regulation. Auditory processing is also poor in this group, which affects their cognitive profile. In addition to the indirect effect of sensory processing pattern, parenting style also has a direct effect on this disorder. Monosensory interventions, the combination of sensory and perceptual-motor methods, and sensory integration are among the common treatments in these people that improve their academy abilities. Also, the working memory capacity decreases in this group, which is more severe in boys (40-49).

LD: learning disability, SMD: Sensory Modulation Disorder, ADHD: Attention Deficit Hyperactivity Disorder, DCD: developmental coordination disorder, SPD: sensory processing disorder

Results

*Sensory p*rocessing disorder

In this category, 5 articles were reviewed, the samples were people with normal growth which showed only sensory processing problems (9-13). Three articles introduced diagnostic ways of this disorder, which were:

1- Encephalographic measurements in children aged 5-12 years showed the uniqueness of brain processing mechanisms in children with SPD compared to children with normal growth (9).
2- Comparison of sensory gate function (The essential function of the brain for filtering the digressive information and selection of related information) between two groups of normal children and with SPD aged 5-12 years old showed that the maturation of this function in the second group is different and later than the first group (10).
3- Diffusion tensor imaging (DTI), in both groups of boys with SPD and normal in the age range of 8-11 years, showed abnormal white matter is a biologic basis for SPD, and this disorder may overlap with autism and attention-deficit hyperactivity disorder (11).

A study which compare the social participation in two groups of 6-9 years old with and without SPD showed a difference in their involvement and enjoyment, and finally Hall et al. examined the effect of voice-based intervention on children aged 5-11 years with SPD and visual-motor delay, which showed improvement in sensory processing behaviors when combining sensory diet and listening therapy (12, 13).

Sensory modulation disorder

In the SPD classification, sensory modulation disorder (SMD) is the most common type. In this section, 5 articles have been presented that have examined this disorder separately (14-18). Two articles in a randomized clinical trial and pilot study showed that sensory integration therapy promoted sensory processing problems, adaptive behaviors, and occupational performance in these children (14, 18). Three articles, which were descriptive, stated hyper or hypo sensivity behaviors, especially in Asperger's children, led to a decrease in social skills and participation in activities and require intervention to facilitate interactions. In these interventions, the areas of social participation, Self-regulation, and competence are the therapeutic priorities of parents (15-17).

Sensory processing disorder in pervasive developmental disorder (PDD)

In this section, SPD disorder in children with ASD was reviewed in 8 articles, which are as follows (19-26). A study with evaluation of white matter using DTI method in three groups with ASD, SPD and no disorder showed that neuronal currents were involved in ASD and there was a relationship between cognitive functions and structural connection of children's brain (19). Also, two articles with comparison of sensory processing in children with ASD and normal growth showed the prevalence and types of sensory processing disorder regardless of their age and clinical characteristics (20, 21). Jasmin *et al.* also with evaluation of 3-4 aged children with ASD observed that abnormal sensory responses have impaired gross and fine motor skills, and daily life activities, even when cognitive dysfunction was not present (22). Contrary to the general consensus on the effect of sensory impairment on social factors, one paper proposed models of ASD theory, according to which the relationship between sense and social function is uncertain and needs to be discussed because different mechanisms may be involved (23). Three articles were related to the evaluation of the sensory integration treatment in these people. In this way, comparing its effect and scenario play on the behavior and participation in the activities of 4 ASD children did not show much difference, while according to the results, sensory integration method had positive effects on the individual during treatment sessions and home environment (24). Also, the comparison of this method and fine motor skills in a randomized clinical trial showed positive changes in goal attainment scale criteria for both groups and further changes and reduction of autistic behaviors for the sensory integration group (25). Thirty sessions of manual sensory integration intervention in another study improved personal care and socialization (26).

Sensory processing disorder in Attention Deficit Hyperactivity Disorder (ADHD)

In the study of SPD disorder in people with attention deficit hyperactivity disorder, 9 articles were found (27-35). A descriptive study showed that sensory response, including hypersensitivity, had an effect on the activity of the hypothalamic-pituitary-adrenal axis (HPA) and there was an association between endocrine neuronal response as well as levels of nerve stimulation and individual behaviors which ADHD classification can be done based on it. (33). In two studies, comparing the children with ADHD and no disorder based on SP test, it was found that the disorder had more problems with sensory processing and higher levels of hyper activity/impulsivity associated with weaker social participation and motor planning (27, 28). Engel-Yeger's research also concluded that all types of ADHD, especially ADD, had a lower preference for participating in recreational activities (34). Also, two articles reported that disorder led to sensory processing impairment and inappropriate behavioral and learning responses (29, 30). In the study by Lane et al. found in both ADHD and normal groups, there was a link between anxiety and hypersensitivity associated with processing differences and defects in the prefrontal cortex and hippocampal synaptic gate (32). One study comparing a visual perception in ADHD groups with and without SPD showed a decrease in visual perception in children with both ADHD and SPD associated with sensory processing, especially vestibular and proprioceptive senses (31). In the field of intervention, wearing a heavy vest (proprioceptive sense) with the promotion of fine motor activity and continuing visual attention had a positive effect on the behavior of ADHD children in the classroom (35).

Sensory processing disorder in developmental coordination disorder (DCD)

An article examining SPD in children with DCD and ADHD separately and in combination together found that SPD increased despite these disorders but varied between individuals and showed the effect of neurological factors (36). Three other articles, considering the motor and postural function of people with concurrent DCD and LD, observed that this comorbidity negatively affects not only the severity of perceptual-motor disorder but also its different patterns (37-39). Also, kinematic analysis of movements in their fine performance showed that these children, in addition to learning problems, also had difficulty in motor learning and relied more on feedback during the execution of movements and had difficulty in using feed forward and open chain

strategies. Also, children with DCD and dyslexia had less postural stability than people without the disorder which these postural fluctuations in dyslexia were of vestibular origin and led to poorer balance in DCD (37-39).

Sensory processing disorder in learning disability (LD)

Children with SPD usually experience academic problems at school age known as LD if they have natural intelligence. According to the inclusion criteria in the current review, 10 articles were selected (40-49). Two studies comparing the sensory processing profiles of children and adults with and without LD showed different processing in the group with the disorder associated with a lack of academic skills (40, 41). Another article stated that the presence of concurrent LD and ADHD, decreased or increased the sensitivity of the sensory threshold, followed by a decrease in the ability of successful praxia in a school, home and community, and more specifically, self-regulation in fine activities (42). A study examining the auditory sensory-perceptual level in these children showed a link between LD neurophysiological assessment, auditory processing, and auditory event reaction potential, and stated that variable auditory processing, specific had cognitive profiles (low vocabulary, and poor spatial reasoning) (43). Another paper found a new relationship with the correlation-modeling method in this way that sensory processing patterns had an indirect effect and parenting styles had a direct effect on LD disorder (44). Four articles were related to sensory interventions and its comparison with other methods and showed 8 weeks of using multisensory intervention in the form of 4 sessions of 45 minutes per week led to a reduction in dyspraxia and dysgraphia in students. Also, comparing this method with perceptual-motor intervention improved the reading skills of dyslexic students during multisensory training in 16 sessions of 60 minutes. Ten sessions of sensorimotor integration treatment in 25 students with special learning disabilities also improved their motor skills, and finally the combination of multisensory training and sensory integration exercises after 20 sessions had a positive effect on the symptoms of reading and writing disorders (45-48). The relationship between working memory and sensory processing styles in children with dysgraphia was as follows: subscales of processing and storage from the working memory variable and subscales of auditory processing, multiple sensory processing and indoctrination related to body posture from the sensory processing styles variable were in a more unfavorable position in boys (49).

Discussion

Encephalography (EEG) measurement of brain activity and processing accurately and with 86% confidence distinguishes children with SPD from normal children, and one of its important functions is to determine sensory gate maturity which is necessary for controlling sensory input, learning and normal activity (10). In fact, the course of growth and maturation of the sensory gate is not the same in all children, and in children with normal growth, the ability to inhibit the brain and regulate sensitivity to sensory stimulation increases with age, and despite SPD, this process occurs slowly (9). Structural differences in the brain are also related to behavior. In this way, decreased sensory integration in the primary posterior white matter (posterior corpus callosum, posterior corona radiata and posterior thalamic radiation) and higher areas in the SPD group and decreased connectivity in the pariatooccipital and temporal filaments are seen in children with autism spectrum and have certain sensory behaviors, and difficulty in auditory processing, and working memory and inattention (11, 19).

It is noteworthy that despite the SPD, the child's participation in social activities is affected. In this way, these children prefer symbolic plays and unregulated dancing, because they have no rules and show defects in performing physical games that require motor planning (12). However, according to the test of Participation in Childhood Occupations Questionnaire (PICO-Q), all three scales of participation (level of activity performance, enjoyment of performance and frequency of performance) depend on the children category and there is a very high correlation between level of activity performance and Short Sensory Profile (SSP) score, moderate correlation between enjoyment of performance and SSP score and low correlation between frequency of performance and SSP score (17). One of the factors influencing this problem is emotional disorders. In this way, at all ages, there is a strong and positive relationship between sensory avoiding and anxiety, and at older ages, between depression and low registration. There is also an inverse relationship between depression and individual skills, between anxiety and individual's functions, and between hypersensitivity/hypersensitivity and social skills (16). In order to increase the participation of these children in the treatment program, it is necessary to pay attention to the context of life, education, and games and the level of support of their parents (15).

Sensory disorders are one of the first symptoms that differentiate infants from 6 months of age and in later years may be known as autism spectrum disorder. The functional and anatomical differences of the thalamus are important as the gateway for the senses entering and the cerebellum as the center

of presenting sensory feedback and social symptom integration in ASD. However, in order to elucidate these mechanisms, more research is needed focusing on the initial deficits in sensory processing and attentional and cognitive functions (23).

According to the SSP overall score, the sensory processing largest differences in the autism spectrum was related to the low registration /sensory seeking pattern, auditory filter, and tactile sensitivity, and 92% of cases showed significant differences in all parts. However, determining the exact pattern of their sensory processing requires further study. This sensory profile affects attention, social interaction, and adherence to norms. On the other hand, changes in the sensory integration of language also disrupt interpersonal communication and function (21, 23).

Diagnosis of SPD in children with ADHD can be done in two ways: by examining the individual's responses to repetitive sensory stimuli through measuring Electro Dermal Response (EDR) and by sensory profile test. Of course, these methods cannot replace with the disorder diagnostic test because it is not clear whether all children in this spectrum show the same sensory profile or not. However, some similarities between the sensory profiles of these children and some adults with mental disorders such as schizophrenia have been seen, which requires further researches (28, 30). When an ADHD is associated with anxiety answers, child responds to behavioral treatment and in case of coexistence with anxiety and sensory over-responsivity, he/she responds to sensory therapy (32). However, contrary to the high prevalence and serious problems associated with ADHD, its etiology and concurrence with other disorders have been less studied (27, 29, 34). Another noteworthy point is that if DCD is associated with ADHD, the probability of SPD will increase in the form of sensory sensitivity. However, in future research, it is better to study larger specimens with the same sex distribution and the neurological mechanism of sensory processing (36).

Impaired processing of proprioceptive, vestibular and tactile senses, despite the lack of detectable neurological disorder in DCD children in the presence of concurrent LD, has a detrimental effect on learning and performance, especially fast, accurate and purposeful movements and dynamic balance. On the other hand, poor static postural control in children with DCD compared to children without the disorder is due to the less ability of the vestibular system to integrate inappropriate visual or somatosensory information, which leads to poorer balance. In children with dyslexia, however, postural stability depends on difficulty and requirements of activity (39). However, more experimental studies are needed for these processes (38). Also, in people with two disorders (LD and DCD), there is a relationship between target size and average movement time. In fact, motor errors are less in discrete activities and more in intermittent activities (37).

In LD children, low sensitivity to various types of sensory information, especially visual and auditory, makes it difficult to store and retrieve information in memory. The high density of sensory experiences and the low ability to filter irrelevant auditory information also lead to poor reading and pronunciation errors. Another problem is more sensory seeking in these children, which causes them to respond hastily and cannot focus on the task for a long time (40, 41). Learning different sciences requires two skills: the ability to use written language and appropriate visual perception. On the other hand, impaired auditory processing has an effect on visual-spatial processing and leads to a lack of stimulus perception. Therefore, the diagnosis of abnormality and its rehabilitation should be done very quickly (43). The important point for therapists is that if they receive educational training instead of services related to the improvement of sensory processing, they will not move in the right direction (44). In the intervention path, the structural differences of the brain between girls and boys in coordination of movements, working memory, and auditory sense are such that in girls, better and more adaptable interaction with the community, parent or teacher can increase the speed of recovery disorders (49).

Sensory-motor learning is the source of all perceptions and learnings, and higher mental processes occur after the development of motor and perceptual systems and the connection between, movement and perception learning (48). Hence, various sensory and perceptual-motor therapies have been designed. Sensory integration therapy is one of the effective interventions in children with SPD that improves the processing and integration of sensory inputs, followed by adaptive behaviors and occupational performance (18). Because it is assumed that if information is received through several senses instead of one sense, learning will be facilitated (14). In children with autism spectrum disorder, this approach improves the social responsibility and caregiver evaluation, and reduces autism behaviors. However, the limitations of the researches were the small number of samples and RCT designs, the short duration of the interventions, and the lack of evaluation of their stability (24-26). Psychotropic drugs are also prescribed in this case, which requires further studies to confirm its effectiveness (27). Also, the combination of multisensory training and this method in LD children led to the improvement of active brain mechanisms and abstract and complex functions such as accuracy, attention, and auditory processing (45).

Conclusion

Finally, it can be said that SPD children usually show significant differences in their brain structure associated with their unusual sensory behaviors. This disorder is seen in various forms and can be associated with psychological disorders such as anxiety and depression. These factors together can impair perceptual, motor, and mental skills and lead to difficulty in daily tasks (schoolwork or self-care) in many children, which sensory processing interventions can be a useful strategy for them.

Suggestions

Due to the effect of SPD on children's perceptual, motor, cognitive and academic skills, determining the sensory disorders and its relationship with other skills and related tests requires more researches for more complete treatments. Also, the effect of combining sensory based-therapies and other methods requires more researches.

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