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Sensory Processing Difficulties and Intervention Approaches in Individuals with Attention Deficit Hyperactivity Disorder

Dikkat Eksikliği Hiperaktivite Bozukluğunda Duyusal İşleme Problemleri ve Müdahale Stratejileri

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is considered one of the most common neuropsychiatric disorders in childhood and causes functional impairment in multiple domains. It is known that ADHD, a lifelong disorder, does not spontaneously disappear. The current approach is that the disorder should be evaluated by including not only behavioral but also cognitive, sensory, motivational and environmental factors. Therefore, instead of focusing only on diagnostic criteria, it is extremely important and necessary to pay attention to the individual characteristics of children diagnosed with attention deficit/excessive movement disorder in order to understand them correctly, to focus on the characteristics underlying the symptoms, and to pay attention to how they receive, process and perceive sensory stimuli for accurate diagnosis and treatment processes. Considering that each individual has a unique profile, it is understood that there are many different factors that trigger attention deficit disorders and hyperactivity. Therefore, this review aims to explore the underlying sensory processing difficulties and intervention approaches in children diagnosed with ADHD through a comprehensive examination of the relevant literature.

Keywords: ADHD, sensory modulation, sensory discrimination, sensory praxis, sensory integration

Özet

Dikkat Eksikliği ve Hiperaktivite Bozukluğu (DEHB) çocukluk döneminde en sık rastlanan nöropsikiyatrik bozukluklardan biri olarak kabul edilmekte ve birden fazla alanda işlevsel bozukluğa yol açmaktadır. Hayat boyu devam eden bir bozukluk olan DEHB'nin kendiliğinden ortadan kalkmadığı bilinmektedir. Güncel yaklaşım, bozukluğu yalnızca davranışsal değil bilişsel, duyusal, güdüsel ve çevresel etkenleri de dahil edilerek değerlendirilmesi gerektiği yönündedir. Bu nedenle yalnızca tanı kriterlerine odaklanmak yerine dikkat eksikliği/aşırı hareket bozukluğu tanılı çocukları doğru anlayabilmek için bireysel özelliklerine dikkat etmek, semptomların altında yatan özelliklere odaklanmak, duyusal uyaranları nasıl aldıkları, nasıl işledikleri ve algıladıklarına dikkat etmek doğru tanı ve tedavi süreçleri için son derece önemli ve gereklidir. Her bireyin kendine özgü bir profili olduğu göz önüne alındığında, dikkat eksikliği bozuklukları ve hiperaktiviteyi tetikleyen birçok farklı etkenin mevcut olduğu anlaşılmaktadır. Bu nedenle bu derlemede ilgili literatür taramaları yapılarak DEHB tanılı çocuklarda semptomların altında yatan duyusal problemler ve müdahale stratejileri açıklanmaya çalışılmıştır.

Anahtar Kelimeler: DEHB, duyusal modülasyon, duyusal diskriminasyon, duyusal praksis, duyusal bütünleme

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1. Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is currently regarded as a multidimensional issue, encompassing not only clinical and behavioral symptoms but also factors related to cognition, sensation, motivation, and environmental influences (Karakaş et al., 2010). Advances in brain imaging studies have led to significant developments in the treatment and approaches to ADHD. However, in our country, the focus tends to remain on the diagnostic criteria for ADHD, often overlooking the underlying causes of these symptoms. Focusing solely on the symptoms can result in gaps in understanding how children with ADHD perceive, process, and respond to information from the external world, which complicates the comprehension of their thinking, perception, and communication skills (Greenspan et al., 2016).

Considering that each individual has a unique profile, it becomes evident that various factors may trigger attention deficits and hyperactivity. Therefore, identifying the individual problems underlying each child's inattention and providing targeted support interventions is of critical importance (Cesur & Köksal Akyol, 2022).

1.1. Physiology of Senses

To understand sensory disorders, it is essential first to examine the physiological foundations of the senses. The brain consists of approximately one hundred billion neurons, which are divided into two groups: sensory and motor neurons. Sensory neurons receive impulses from receptors in structures such as the eyes, ears, skin, and muscles, transmitting this information to other neurons via synapses (Kranowitz, 2015). These neurons carry the received information to relevant centers in the brain, where it is processed (Mather, 2018). After interpreting these sensory messages, the brain sends motor messages to the spinal cord, which in turn transmits these signals to peripheral nerves through motor neurons, regulating responses in various parts of the body. As sensory responses increase, the process of myelination, which covers the axons of neurons and speeds up impulse transmission, is strengthened (Aamodt & Wang, 2018). Increased myelination indicates a more robust neurological structure, enhancing children's ability to learn new skills (Albayrak Sidar, 2019; Kranowitz, 2015).

Dr. Paul D. MacLean's "triune brain" model proposes that the human brain developed in layers. The first layer, known as the "reptilian brain," is responsible for survival and instinctual functions. The brainstem, a part of this layer, processes vestibular information essential for balance and attention, while the cerebellum coordinates proprioceptive and vestibular senses (Carter, 2019). Recent research has also linked the cerebellum to cognitive and emotional functions (Strick et al., 2009).

The second layer, known as the "limbic system," processes emotional states as well as the senses of smell and taste. One of the key components of the limbic system, the hippocampus, compares new and old stimuli, while the amygdala manages emotional responses (Kranowitz, 2015). The hypothalamus controls various physical states, and the thalamus functions as the central hub for processing all sensory inputs, except for smell (Carter, 2019). The basal ganglia, located between the brain's lower and upper layers, facilitate interaction between these regions. They play a role in

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movement, emotion, motivation, and cognitive functions, helping to automate physical skills by utilizing information stored in memory (Albayrak Sidar, 2019).

The brain's upper layer, known as the "cerebrum," houses the cerebral cortex, which is responsible for organizing complex sensory inputs. This region is where higher-level mental processes such as conscious perception, abstract thinking, and planning occur (Goldstein, 2019). The corpus callosum, which connects the brain's two hemispheres, ensures coordinated functioning between the two halves (Siegel & Bryson, 2015). Each hemisphere contains four cortical lobes that process sensory information: the occipital lobe is responsible for vision, the parietal lobe for body sensations, the temporal lobe for hearing and memory, and the frontal lobe for higher-order thinking, speech, planning, and problem-solving (Carter, 2019; Kranowitz, 2005). Additionally, the frontal lobe plays a crucial role in integrating signals from all senses, facilitating the coordination of multiple sensory inputs (Goldstein, 2019).

The effective processing of sensory inputs directly impacts a child's development; when this process is not synchronized, the child struggles to receive, process, and organize information, which negatively affects learning (Greenspan et al., 2016). Sensory inputs are collected by the peripheral nervous system and transmitted to the lower brain, from where they are relayed to the midbrain. Sensory information reaching the limbic brain determines the emotional response and is then sent to the upper brain. The upper brain gathers, processes, and organizes this information to produce appropriate, meaningful behaviors, coordinating both motor and emotional responses. The more efficient the lower brain is at collecting sensory information, and the midbrain at associating this information with emotions, the more functional the upper brain becomes in managing higher-order cognitive skills and emotional regulation (Aamodt & Wang, 2018; Albayrak Sidar, 2019).

1.2. Attention Deficit/Hyperactivity Disorder

ADHD was first described in 1902 by British pediatrician George Still. Still attributed the disorder to individual difficulties that children face in regulating their behavior, controlling motivation, and managing impulses, suggesting that these challenges had a neurobiological basis. Until the 1970s, ADHD was referred to by different names, but it was reconsidered in more detail when it became evident that its symptoms were not limited to hyperactivity but also included inattention. During this period, the disorder's name was changed to "Attention Deficit Disorder." Later, impulsivity and alertness issues were recognized as part of the clinical picture, leading to the definition of subtypes based on the presence or absence of impulsivity and hyperactivity (Soysal & Karakaş, 2010). The disorder was later renamed "Attention Deficit Hyperactivity Disorder." Research between 1980 and 2000 showed that ADHD is not limited to childhood and does not naturally resolve. By the 2000s, it became clear that ADHD is a lifelong condition (Ercan & Aydın, 2011).

ADHD is considered one of the most common neuropsychiatric disorders in childhood, causing functional impairments across multiple domains (Biederman, 2005; Hoogman et al., 2017). Studies involving families, adoption, and twins have demonstrated that ADHD is a complex multifactorial disorder that arises from the interaction of genetic, biological, and environmental factors

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(Gücüyener, 2010), with heritability estimated at 80% (Kılıç et al., 2016). In addition, prenatal exposure to alcohol and smoking (Kılıç et al., 2016), poor maternal health during pregnancy, eclampsia, prenatal bleeding, prolonged and difficult labor (Öner & Soykan Aysev, 2007), and low birth weight (Kavakcı & Yelboğa, 2016) are also considered significant risk factors for ADHD.

The diagnostic criteria for ADHD, as established by the American Psychiatric Association (APA), consist of eighteen symptoms. For a diagnosis to be made, at least six of these symptoms must have been observed for at least six months in a manner inconsistent with the individual's developmental level, and symptoms must have started before the age of twelve. ADHD is classified into three subtypes based on the predominant symptoms: "predominantly inattentive type, predominantly hyperactive-impulsive type, and combined type" (APA, 2013). Inattention is characterized by difficulty focusing on tasks, inability to complete tasks, limited attention span, and distractibility, all disproportionate to the individual's cognitive capacity and age. Hyperactivity is defined as a constant need for movement, the desire to engage in multiple activities simultaneously, and a need to be in motion, all inconsistent with developmental norms (Gücüyener, 2010). Impulsivity refers to difficulty controlling oneself, impatience, answering questions before they are finished, making quick decisions without thinking, and difficulties with anger management (Chamberlain & Sahakian, 2007).

Although ADHD symptoms typically emerge around the age of three, they can be difficult to detect at that time, as hyperactivity and impulsivity are often considered normal developmental behaviors (Şenol & Sosyal, 2010). However, as children are expected to become more disciplined and academic success becomes important in the school years, ADHD symptoms become more noticeable. Therefore, clinical referrals and assessments often increase during the school period (Kaymak Özmen, 2010). In the diagnosis and evaluation processes, it is crucial to assess the child's emotional and behavioral traits in both home and school settings and to evaluate the interactions between the child and their parents and teachers. Additionally, the school and home environments should be carefully examined for stress factors (Kaymak Özmen, 2010).

Common complaints from families about ADHD include their children's reluctance to engage in tasks that require sustained attention, which results in prolonged homework completion times, frequent loss of belongings, disorganization, abandoning tasks halfway, and the need for constant supervision and support (Cesur & Köksal Akyol, 2019; Öner & Soykan Aysev, 2007).

ADHD symptoms vary according to the developmental stage. In infancy, signs such as excessive dependence on the mother, sleep irregularities, short sleep duration, and eating problems may be observed (Soykan Aysev & Erdoğan Bakar, 2010). During early childhood, symptoms like hyperactivity, difficulty in establishing play, problems with peer relationships, a lack of goal-directed behavior, and disobedience become more prominent (Soykan Aysev & Erdoğan Bakar, 2010; Schachar & Tannock, 2002). In school-aged children, inattention becomes more dominant (Kaymak Özmen, 2010), while in adolescence, hyperactivity decreases but impulsive behavior and attention difficulties become more apparent (Schachar & Tannock, 2002). At this stage, difficulties in social relationships, aggressive attitudes, negative self-perceptions, and antisocial behaviors are frequently observed (Hallowell & Ratey, 2022).

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Neuroimaging studies with individuals diagnosed with ADHD have revealed some structural changes in the brain. The globus pallidus and caudate nucleus, responsible for coordinating neural inputs in various regions of the cortex, are smaller in individuals with ADHD (Frodl & Skokauskas, 2012; Nakao et al., 2011). These structures play crucial roles in inhibiting automatic responses and controlling attention (Castellanos et al., 2002). Additionally, the cerebellum, which is associated with reduced metabolic rates, integrates proprioceptive and vestibular senses, regulates muscle tone, maintains balance, and coordinates body movements. Recent research has shown that the cerebellum not only plays a role in motor functions but also integrates cognitive processes, emotional states, sensory perception, and attention functions (Strick et al., 2009). These findings provide important insights into the sensory and cognitive challenges observed in children with ADHD.

The corpus callosum, which is responsible for the brain's motor and attention systems (Gücüyener, 2010), allows the two hemispheres of the brain to work together in an integrated manner (Siegel & Bryson, 2015). By ensuring the coordinated functioning of sensory processing regions, the corpus callosum enables the reception, processing, organization, and learning of information (Horowitz & Röst, 2007; Kranowitz, 2015). The smaller size of the corpus callosum in children with ADHD provides crucial clues to the sensory, cognitive, and emotional challenges these children face. Additionally, the limbic system, which is responsible for emotion formation, and the amygdala, which regulates the stress response and impulses, have higher cortical functions (Barkley, 2010; Malisza et al., 2011). This neurological explanation sheds light on the emotional regulation difficulties and behavioral problems seen in children with ADHD. Finally, the premotor cortex, which assists the motor cortex and is responsible for movement planning and execution, and the prefrontal cortex, which oversees higher-order mental functions such as planning, problem-solving, cognitive flexibility, and self-regulation, have been reported to be smaller in children with ADHD. This provides critical insights into the underlying causes of the challenges these children face (Gücüyener, 2010).

Although the diagnostic criteria for ADHD, as outlined by the American Psychiatric Association (APA), do not explicitly include emotional problems, leading researchers in the field argue that emotional dysregulation should be considered among the diagnostic criteria for ADHD (Barkley, 2010; Brown, 2014). Studies have shown that children with ADHD struggle to disengage from negative emotions and are prone to difficulty in interpreting events or others' behaviors from different perspectives. They often find it challenging to shift their focus away from negative emotions and existing thought patterns, particularly in situations involving anxiety, depression, or conflict, which intensifies these conditions (Shechner et al., 2012; Seymour et al., 2012). These children tend to become overwhelmed by frustration, boredom, or other negative emotions and have difficulties managing emotions that would help sustain motivation (Brown, 2014). Furthermore, because they struggle to understand and regulate their emotions, they may exhibit sudden emotional outbursts, leading them to display more aggressive and confrontational behavior compared to their peers (Greenspan et al., 2016).

In ADHD assessments, structured or semi-structured interviews are preferred to ensure clinical accuracy. According to DSM diagnostic criteria, symptoms must be present in more than one setting, making it crucial to gather information from various sources during the evaluation process. ADHD

diagnosis primarily relies on a comprehensive anamnesis. In certain cases, physicians may also perform physical examinations and laboratory tests to confirm the anamnesis (Ercan & Aydın, 2011; Öner & Soykan Aysev, 2007). In addition, conducting general medical assessments, evaluating the child's developmental status, and holding interviews with both the child and the caregiver are critical components for an accurate diagnosis (Şenol et al., 2014).

1.3. Sensory Problems in ADHD

In recent years, ADHD has been approached from a multidimensional perspective, taking into account cognitive, sensory, motivational, and environmental psycho-sociocultural factors (Karakaş et al., 2010). Sensory problems associated with ADHD have gained increasing attention in contemporary research. It has been identified that these children experience varying degrees of difficulties in tactile, auditory, olfactory, and movement senses, as well as in visual-spatial perception, motor planning, information processing, and sequencing skills (Cesur & Demirci, 2024; Greenspan et al., 2016; Horowitz & Röst, 2007). To understand the reasons behind these issues, it is essential to first explain how sensory information is processed in the brain and how this information is transformed into behavioral responses.

The brain receives millions of stimuli from the environment every second. However, it is not possible to be aware of, process, and manage all of these stimuli simultaneously, which is where the concept of "threshold value" comes into play. The brain amplifies the stimuli deemed important enough to exceed the threshold value and sends them to higher centers for processing. Meanwhile, insignificant stimuli are kept below the threshold, preventing them from reaching the level of conscious awareness (Goldstein, 2019; Mather, 2018). This ability of the brain is referred to as sensory modulation (Albayrak Sidar, 2019).

Stimuli that exceed the brain's threshold value and are sent to higher centers for processing are converted into perception within the relevant brain regions. This process is known as "sensory discrimination," during which the brain seeks to answer questions related to the stimuli, such as "what, where, and how," analyzing the stimuli in greater detail. Through this process, sensory information is differentiated, providing a detailed understanding (Miller et al., 2007). The subsequent stage, referred to as "sensory praxis," is where the stimuli converted into perception are interpreted, and decisions are made regarding what actions to take. Also known as "motor planning," this phase involves the planning of physical movements. This process encompasses skills such as fine and gross motor skills, oral-motor coordination, eye muscle coordination, muscle tone, balance, and sequential movements (Horowitz & Röst, 2007; Kranowitz, 2005).

Each individual has a different sensory threshold level, leading to variations in sensory modulation, discrimination, and praxis processes from person to person. These differences can affect an individual's perceptual, physical, social, and emotional functioning (Emmons & Anderson, 2006). Individuals with a high sensory threshold may not perceive incoming stimuli as sufficiently important during the modulation phase, resulting in a reduced amount of stimuli that reach the brain's higher centers for perception. This situation may lead to the individual being unresponsive to environmental

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stimuli. Conversely, individuals with a low sensory threshold process all stimuli indiscriminately, leading to an excessive sensory load and heightened sensitivity (Albayrak Sidar, 2019).

Children with a low sensory threshold may feel discomfort due to perceiving numerous stimuli simultaneously and may withdraw to protect themselves from external stimuli or struggle to focus their attention on a specific point. In contrast, children with a high sensory threshold may exhibit more active behaviors to reach an adequate level of stimulation and may present themselves through disorganized and uncoordinated motor movements (Greenspan & Greenspan, 2009; Miller et al., 2007). The responses of children with sensory modulation disorders can vary depending on time, space, and the type of stimulus (Cermak & Mitchell, 2006).

Children diagnosed with ADHD often exhibit significant difficulties in the modulation of auditory, tactile, and emotional inputs (Dunn & Bennett, 2002; Yochman et al., 2004). These children frequently demonstrate tactile sensitivity (Lane et al., 2010; Parush et al., 2007). Research has identified strong correlations between tactile modulation disorders and anxiety disorders (Lane et al., 2010; Reynolds & Lane, 2009).

Children with difficulties in the sensory discrimination process are unable to accurately distinguish and perceive stimuli, and therefore have difficulty developing appropriate motor responses to these stimuli (Miller et al., 2007). Children with auditory discrimination problems have difficulty distinguishing tones of voice; for example, they have difficulty distinguishing whether a word is spoken in an angry or calm tone, or similar sounds such as “b” and “p”. They also have difficulty identifying the direction, intensity and type of sound, making it difficult for them to follow complex verbal instructions. Children with visual discrimination difficulties have difficulty with writing, distinguishing differences or similarities between three-dimensional objects, and judging distance. Children with tactile discrimination difficulties may not perceive the texture, temperature or hardness of objects they touch and may have difficulty writing. Children with taste and smell discrimination difficulties have trouble distinguishing between different tastes and smells and may not be able to identify the source or intensity of an odor. Children with vestibular discrimination problems cannot accurately perceive the details of movement, which causes them to have difficulty with activities that require complex movements, such as dancing. They may have difficulty catching a ball or following writing on a blackboard because they cannot accurately predict the speed and direction of movement. Because they have poor balance, they tire quickly and may have difficulty with writing. They may also dislike movement or, on the contrary, exhibit constant jumping, running, turning or rocking behaviors in order to process sensory input. Children with proprioceptive discrimination problems, on the other hand, have difficulty with postural skills and it is very difficult for them to learn new motor skills. They may have difficulty applying sufficient and correct force; their touch may be either too hard or too light to be felt. These children who have difficulty with writing may enjoy activities such as collisions or falls and may normalize behaviors such as hitting and pushing to meet their sensory needs, which may disturb the other person (Albayrak Sidar, 2019; Cesur & Köksal Akyol, 2024; Greenspan et al., 2016).

Studies involving individuals diagnosed with ADHD report that they struggle with perceiving and

processing sensory information, specifically in the area of discrimination (Engel Yeger & Ziv On, 2011; Shimizu et al., 2014; Yochman et al., 2004). In children diagnosed with ADHD, auditory discrimination disorders, which often increase with age, are commonly observed (Cheung & Siu, 2009). Research indicates that these children also experience visual and tactile discrimination disorders (Schaughency, 1986), along with issues related to abnormal muscle tone, balance problems, and difficulties in hand-eye coordination (Hern & Hynd, 1992), as well as challenges in repetitive movements, coordination, balance, and movement control (Gustafsson et al., 2000; Dickstein et al., 2005; Sergeant, 2005). Additionally, significant deficits in both fine and gross motor skills have been reported (Pitcher et al., 2003).

Children with praxis disorders frequently exhibit postural problems, difficulties in movement planning, balance issues, and challenges in complex motor skills (Kranowitz, 2015; Miller et al., 2007). Therefore, what may seem like simple sequences of movement can be quite challenging for children with ADHD. For instance, understanding the teacher's instructions to sit and remain quiet during class, stopping their current behavior, moving to their seat, sitting still, and staying quiet requires complex planning and sequencing skills (Greenspan et al., 2016). These children, who struggle with sensory praxis skills, exhibit not only weaknesses in higher brain functions related to balance and motor planning but also difficulties in imagination, idea generation, problem-solving, self-regulation, and planning (Emmons & Anderson, 2006). Such difficulties can lead ADHD children to struggle with reorganizing and adapting to changes or disruptions in their plans, resulting in aggressive responses or outbursts of anger (Albayrak Sidar, 2019; Cesur & Köksal Akyol, 2024; Kranowitz, 2015).

The sensory problems observed in ADHD can vary significantly based on each child's individual characteristics. Therefore, to accurately understand children with ADHD, it is crucial to pay attention to their unique traits, focus on the underlying characteristics of their symptoms, and observe how they receive, process, and perceive stimuli. This understanding is essential for proper diagnosis and treatment processes.

1.4. Intervention Approaches in ADHD

Currently, pharmacological, behavioral, combined treatments, and alternative approaches are frequently used in the treatment of children diagnosed with ADHD. There is no consensus on which method is more effective. However, professionals in the field are working to compare different treatment methods to determine the most comprehensive approach for children with ADHD.

Literature suggests that combined treatments are more effective than behavioral (MTA, 1999; Pelham et al., 2000) and pharmacological treatments (MTA, 1999). Additionally, studies have shown that behavioral modification methods taught to teachers of children with ADHD, cognitive-behavioral strategies, and classroom management techniques positively affect ADHD symptoms in children (Miranda et al., 2002). There are also numerous studies demonstrating the effectiveness of family education programs for parents (Herbert et al., 2013; Lee et al., 2012; Matos et al., 2009; Webster Stratton et al., 2011).

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With the emergence of a multidimensional perspective on ADHD, alternative treatments have also been introduced. Research indicates that physical activity can lead to a reduction in ADHD symptoms (Azrin et al., 2006; Verret et al., 2012), while meditation practices have been shown to decrease anxiety and negative mood symptoms, as well as support attention and focus skills (Zylowska et al., 2008). Moreover, yoga exercises have been found to have a symptom-reducing effect (Cerrillo Urbina et al., 2015). Similarly, there are studies showing that mindfulness-based interventions have a positive effect on attention, hyperactivity and impulse control in children with ADHD (Evans et al., 2018; Lee et al., 2022; Vekety, 2021). One study focused on perceptual skills demonstrated improvements in both ADHD symptoms and the functional emotional development of the child and mother as a result of an intervention program implemented with a child diagnosed with ADHD and their mother (Larasati et al., 2017). In another study, a program aimed at supporting the perceptual processes of children diagnosed with ADHD incorporated muscle and breathing exercises, along with sensory, cognitive, and emotional perception activities involving family members in each session. The results showed improvements in the sensory, cognitive, and emotional perception processes of the children, as well as a reduction in ADHD symptoms. Additionally, an increase in family functionality was noted (Cesur & Köksal Akyol, 2022).

As evidenced by various studies, the effects of solely using medication in the treatment of ADHD are quite limited. It is clear that alternative treatment methods developed in light of current knowledge about the disorder, behavioral training, and support programs focusing on perceptual processes have positive effects on children's symptoms. Research has demonstrated that underlying sensory problems contribute to the symptoms in children diagnosed with ADHD, leading to an increased interest in sensory integration therapies in recent years.

Sensory integration is a neurological process through which an individual processes sensory information from both their body and external environment, allowing them to use their body effectively. This process consists of a series of functional steps involving different stages of the central nervous system's ability to perceive, regulate, interpret sensory information, and develop appropriate responses (Albayrak Sidar, 2019; Kranowitz, 2005). Sensory integration approaches can be examined under two main headings: Ayres Sensory Integration Theory and sensory-based approaches (Watling & Hauer, 2015). Although both approaches address the processing and integration of sensory information, they differ in methods and applications. Ayres Sensory Integration Theory is a neurodevelopmental theory focusing on the central nervous system's capacity to process and organize sensory information. This approach offers structured and individualized interventions that are implemented solely within specific protocols by trained professionals. Treatment is conducted in a controlled therapeutic environment and involves the active participation of the individual to promote the development of sensory integration. Throughout the therapy process, various sensory experiences such as swinging, balance exercises, and tactile and kinesthetic stimuli are provided to help regulate the individual's sensory responses (Ayres & Robbins, 2005).

On the other hand, sensory-based approaches do not exhibit as rigid a structure as Ayres's theory; they encompass a variety of sensory interventions within a broader framework. These approaches aim

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to meet individuals' overall sensory needs and focus on making sensory processing skills more functional in daily life activities. Sensory-based approaches are more flexible in application and can be implemented in different contexts, such as classroom settings, at home, or through play therapy. Various tools, such as sensory materials (e.g., weighted blankets, fidget toys) and sensory strategies (e.g., sensory breaks), can be utilized during this process. These approaches are designed to address individuals' sensory needs in daily life and generally target a wide population (Bundy et al., 2002).

There is a limited amount of academic research on the effectiveness of sensory integration practices in children diagnosed with ADHD. Studies utilizing sensory-based approaches (Chu, 2003; Doğru et al., 2020; Gharebaghy et al., 2014; Lee & Song, 2015; Shaffer et al., 2001) and those employing Ayres Sensory Integration Theory (Balıkçı et al., 2021; Lee et al., 2018; Jung et al., 2024) indicate that sensory integration is quite effective in the treatment of ADHD. These studies demonstrate that children with ADHD participating in sensory integration practices show progress in areas such as sensory processing, gross motor skills, hand-eye coordination, body coordination, muscle strength and agility, attention, social skills, collaboration, and self-esteem.

2. Conclusion

Given that sensory processes are fundamental to cognitive and emotional functions, it is evident that they represent a crucial area of focus for children with ADHD. Children who struggle with processing sensory information may encounter various difficulties while trying to adapt to new experiences or complete tasks that their peers can easily perform. This situation can negatively impact the development of cognitive skills and emotional processes. Differences in processing stimuli can lead to the child easily losing attention, feeling restless, becoming fatigued quickly, or exhibiting excessive and clumsy movements (Cesur & Köksal Akyol, 2024; Greenspan et al., 2016; Kranowitz, 2015).

Research has shown that children diagnosed with ADHD experience varying degrees of difficulty with touch, hearing, smell, movement senses, as well as visual-spatial perception, motor planning, information processing, and sequencing skills (Cesur & Demirci, 2024; Greenspan et al., 2016; Horowitz & Röst, 2007). In particular, there are issues with the modulation of auditory, tactile, and emotional inputs (Dunn & Bennett, 2002; Yochman et al., 2004), and they often exhibit tactile sensitivity (Lane et al., 2010; Parush et al., 2007). Sensory discrimination difficulties have been identified (Cheung & Siu, 2009; Engel Yeger & Ziv On, 2011; Shimizu et al., 2014; Yochman et al., 2004), along with impairments in visual and tactile discrimination (Schaughency, 1986). Additionally, there are issues related to abnormal muscle tone, balance problems, and difficulties in hand-eye coordination (Hern & Hynd, 1992), as well as challenges in repetitive movements, coordination, balance, and movement control (Gustafsson et al., 2000; Dickstein et al., 2005; Sergeant, 2005). Furthermore, significant deficits in both fine and gross motor skills have been noted (Pitcher et al., 2003).

ADHD, which can be managed with early diagnosis, appropriate treatment, and suitable intervention programs, requires an approach focused on understanding how children perceive, process, and respond to sensory information, rather than merely addressing the observable behavioral symptoms.

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As research has shown, while ADHD symptoms may appear similar, the underlying causes of these symptoms can differ significantly (Cesur & Köksal Akyol, 2022; 2024). The brain possesses a characteristic known as neuroplasticity, which allows it to continuously develop in response to thoughts and experiences. This means that the number of neural regions responsible for specific tasks can be increased or decreased; connections between these regions can be strengthened or weakened; and the activation levels within brain circuits can be heightened or diminished (Costandi, 2024). Therefore, understanding the neurological and physiological processes underlying issues associated with ADHD will serve as a crucial guide for developing more suitable and effective treatment and intervention programs for these children. When sensory processing occurs healthily, children are better equipped to make decisions, learn more easily, and gain improved control over their bodies and emotions (Emmons & Anderson, 2006; Goldstein, 2019), thus maximizing the benefits of support interventions.

Authors Contributions

Topic selection: EC; Design: EC; Planning: EC; Writing of the article: EC; Critical revision: EC.

Conflict of Interest

This review has no conflict of interest with any person or organization.

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