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Sensory processing disorder in Saudi children with and without neurodevelopmental disorders

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Abstract

Background: Sensory processing disorder (SPD) is commonly associated with neurodevelopmental conditions such as attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and global developmental delay. This study aimed to evaluate the sensory profiles of Saudi children with and without neurodevelopmental disorders (NDDs) and to explore the influence of demographic factors such as age and gender on these profiles.

Methods: This cross-sectional study was conducted at Center for Developmental and Behavior Disorders from 1/9/2024 to 1/11/2024. It included 83 Saudi children, comprising 49 children diagnosed with NDDs and 34 typically developing (TD) children. SPD was assessed in the participants using the Short Sensory Profile. Statistical analysis included gamma coefficients to compare sensory dimensions between the two groups, as well as to assess the strength and direction of associations between gender and the ordinal sensory dimensions. Additionally, ANOVA was employed to examine associations between age groups and sensory dimensions.

Results: Among NDDs, ADHD was the most common diagnosis (25.3%), followed by autism (15.7%). Children with NDDs showed significantly higher rates of sensory processing challenges compared to TD children, with the strongest deficits observed in auditory filtering (gamma = -0.785, p = 0.0005) and under-responsiveness/seeks sensation (gamma = -0.764, p = 0.0005). Age had no significant effect on most sensory dimensions, except for under-responsiveness/seeks sensation in children with NDDs (p = 0.045). Gender was associated with movement sensitivity in TD children (p = 0.047) and taste/smell sensitivity in children with NDDs (p = 0.036).

Conclusion: The findings highlight significant sensory processing challenges in children with NDDs, particularly in auditory filtering and sensory seeking behaviors. Age- and gender-specific variations emphasize the need for tailored, collaborative interventions among parents, teachers, and healthcare providers to enhance sensory processing and improve developmental outcomes and quality of life.

Keywords: Sensory processing disorder, Neurodevelopmental disorders, Autism, Saudi children, Sensory profiles

1- Introduction

1-1- Research Background

Sensory Processing Disorder (SPD) is increasingly recognized as a significant neurodevelopmental condition that affects children's ability to interpret and respond to sensory information from their environment [1]. This disorder can manifest in various ways, leading to difficulties in daily functioning, social interactions, and overall quality of life. SPD is not a standalone diagnosis but is often found alongside other neurodevelopmental disorders (NDDs), such as Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) [2]. The prevalence of SPD is particularly notable among children with NDDs, where it can range from 20% to 95%, depending on the specific disorder and the population studied [3,4].

The heterogeneity of SPD is a defining characteristic, as it can affect multiple sensory modalities, including tactile, auditory, vestibular, proprioceptive, and interoceptive systems. This complexity necessitates the use of classification frameworks to better understand and assess SPD. Miller's model categorizes SPD into three primary subtypes: sensory modulation disorder (SMD), sensory-based motor disorder (SBMD), and sensory discrimination disorder (SDD) [5]. These subtypes can coexist and interact in various combinations, complicating diagnosis and treatment. Schaaf's model further expands on this by identifying specific sensory patterns and deficits, which can be assessed using standardized tools like the Ayres Sensory Integration Assessment [6].

SPD is prevalent in 3–16% of the general population and significantly more common in children with neurodevelopmental disorders (NDDs), where rates range from 20% to 95% depending on the condition and population studied (7, 8). For example, sensory processing challenges affect 80–90% of children with ASD, contributing to difficulties in communication, social interactions, and adaptability (9, 10). Approximately 60% of children with ADHD also exhibit sensory processing difficulties, such as sensory seeking or under-responsivity (5). SPD has been observed in 49% of children with Down syndrome (11) and is frequently associated with conditions such as epilepsy (12) and urinary incontinence (13).

Although the etiology of SPD remains unclear, several risk factors have been identified. Prenatal and perinatal complications, such as prematurity, low birth weight, and maternal substance use, are associated with an increased risk of SPD. Studies indicate that 46% of children born before 32 weeks of gestation display sensory processing difficulties by the age of four (14). Environmental factors, including parental stress, limited sensory stimulation, and substance use, also contribute to SPD development (15, 16). Genetic factors are implicated, with evidence suggesting heritability of sensory processing traits (17).

The effects of SPD on children can be profound, influencing academic performance, social skills, and emotional well-being. Children with SPD often exhibit hyperactivity, distractibility, and poor motor planning, which can lead to secondary issues such as low self-esteem and anxiety. These challenges are particularly evident in school-aged children, where sensory difficulties can interfere with learning and peer relationships. The comorbidity of SPD with other conditions, including anxiety and externalizing behaviors, further complicates the landscape, emphasizing the need for early identification and intervention.

The impact of SPD on children is profound, affecting academic performance, motor coordination, and social participation. Hyperactivity, distractibility, and poor motor planning are common, often leading to secondary issues such as low self-esteem, anxiety, and social withdrawal (18-20). These challenges are particularly pronounced in school-aged children, where sensory difficulties can interfere with learning and peer relationships (21, 22). Despite its high prevalence and significant impact, SPD remains underdiagnosed due to the lack of validated biomarkers and reliance on observational assessments (8).

Current SPD assessments rely on behavioral observations and caregiver reports, with tools such as the Sensory Profile (SP) and Sensory Integration and Praxis Test (SIPT) being widely used (23). The Short Sensory Profile, a streamlined version of the SP, is frequently employed in research and epidemiological studies for its simplicity and reliability (7, 24, 25). Efforts to develop objective biomarkers, such as electroencephalography (EEG) (26) and diffusion tensor imaging (DTI) (27), have shown promise but require further validation for clinical use.

While significant progress has been made globally, research on SPD within the Saudi Arabian context is limited. Cultural practices, environmental factors, and healthcare access likely influence the presentation and management of SPD in this population. Al-Heizan et al. highlighted a high prevalence of sensory difficulties in Saudi children with ASD, emphasizing the need for culturally tailored diagnostic and therapeutic strategies (28). Addressing these gaps is critical for improving the quality of care and outcomes for children with NDDs in Saudi Arabia.

1-2- Research Problem

Despite the growing awareness of Sensory Processing Disorder (SPD) and its significant impact on children, there remains a considerable gap in understanding its prevalence and characteristics, particularly in the context of Saudi Arabia. The existing literature primarily focuses on Western populations, leaving a dearth of research on how cultural, environmental, and healthcare factors in Saudi Arabia may influence the manifestation and management of SPD.

Children with neurodevelopmental disorders (NDDs) in Saudi Arabia may experience unique challenges related to sensory processing, yet there is limited empirical data to support this assertion. The high prevalence of sensory difficulties in children with ASD, as highlighted by previous studies, underscores the importance of investigating sensory processing patterns in this population [7-13]. Furthermore, the lack of validated assessment tools and culturally relevant diagnostic criteria poses a significant barrier to effective identification and intervention for SPD in Saudi children [18-22].

The research problem is further complicated by the comorbidity of SPD with other neurodevelopmental conditions, which can obscure the diagnosis and treatment of SPD. Many children with NDDs may exhibit sensory processing issues that are overlooked or misattributed to other behavioral or developmental concerns. This lack of clarity can lead to inadequate support and intervention, ultimately affecting the child's developmental trajectory and quality of life.

Additionally, demographic factors such as age and gender may play a crucial role in shaping sensory processing profiles [8], yet there is limited research exploring these influences within the Saudi context. Understanding how these factors interact with sensory processing can inform tailored interventions and support strategies that address the specific needs of children in this population. Overall, the research problem centers on the need for a comprehensive investigation of sensory processing patterns in Saudi children with and without neurodevelopmental disorders, utilizing culturally relevant assessment tools to identify potential disparities and inform effective intervention strategies.

1-3- Aim and Objectives

This research aims to investigate sensory processing patterns in Saudi children with neurodevelopmental disorders (NDDs) compared to typically developing (TD) children, utilizing the Short Sensory Profile to assess various sensory dimensions.

Objectives:

- To assess sensory processing patterns in Saudi children with NDDs using the Short Sensory Profile.
- To compare sensory processing profiles between children with NDDs and TD children.
- To examine the influence of demographic factors (age and gender) on sensory processing patterns in both groups.
- To identify specific sensory challenges faced by Saudi children with NDDs to inform culturally relevant intervention strategies.

1-4- Research Significance

The significance of this research lies in its potential to fill critical gaps in the understanding of Sensory Processing Disorder (SPD) within the Saudi context, particularly regarding children with neurodevelopmental disorders (NDDs). By investigating sensory processing patterns in Saudi children, this study aims to provide valuable insights that can inform diagnostic practices, therapeutic interventions, and policy development in the region.

This research will contribute to the limited body of knowledge on SPD in non-Western populations, particularly in Saudi Arabia. Understanding how cultural practices and environmental factors influence sensory processing can lead to more effective and culturally sensitive diagnostic and therapeutic approaches.

By utilizing the Short Sensory Profile to assess sensory processing patterns, this study aims to enhance the identification of SPD in children with NDDs. Early diagnosis and intervention are crucial for mitigating the long-term impacts of sensory processing difficulties on academic performance, social interactions, and emotional well-being.

The findings will help identify specific sensory challenges faced by Saudi children with NDDs, enabling healthcare professionals, educators, and families to develop tailored support strategies. This can lead to improved outcomes for children, fostering their development and enhancing their quality of life. The research will provide evidence-based recommendations for policymakers and practitioners in Saudi Arabia, advocating for the integration of sensory processing assessments in routine evaluations of children with NDDs. This can promote the adoption of best practices in the identification and management of SPD. This study will lay the groundwork for future research on SPD in Saudi Arabia, highlighting the need for further exploration of sensory processing issues in diverse populations. It can inspire subsequent studies to investigate the neurobiological underpinnings of SPD and the effectiveness of various intervention strategies.

2- Literature Review

SPD is noted for its heterogeneous presentations, leading to the establishment of various theoretical frameworks for classification. **Miller's Model** categorizes SPD into three main subtypes:

1. **Sensory Modulation Disorder (SMD)**: Involving over- or under-responsiveness to sensory input.
2. **Sensory-Based Motor Disorder (SBMD)**: Affecting coordination and motor planning.
3. **Sensory Discrimination Disorder (SDD)**: Impeded ability to differentiate between various sensory stimuli [36].

These subtypes can coexist, complicating the clinical picture of SPD [36].

Schaaf's Model further contributes to understanding SPD by identifying specific sensory processing patterns, such as **somatic dyspraxia** and **vestibular-bilateral integration deficits**. Assessment tools such as the **Ayres Sensory Integration Assessment** are utilized to detect these patterns, allowing for a more nuanced approach to understanding sensory challenges [37].

2-1- SPD and Neurodevelopmental Disorders

A substantial body of literature documents the high prevalence of SPD among children with various NDDs. The relationship between SPD and conditions like ASD, ADHD, and Down syndrome demonstrates the integral role sensory processing plays in broader developmental trajectories. For instance, children with ASD often face significant sensory challenges, impacting their ability to communicate and engage socially [38]. Research indicates that sensory difficulties not only exacerbate the core symptoms of ASD but also contribute to behavioral issues, anxiety, and impaired adaptive functioning [39]. Additionally, children with ADHD frequently exhibit sensory-seeking behaviors and sensory modulation issues, which can hinder their attentiveness and academic performance [40]. Moreover, sensory processing problems have been reported in numerous conditions, including **epilepsy**, **Down syndrome**, and other NDDs, underlining the pervasive nature of sensory difficulties across typical developmental trajectories [41].

2-2- Etiology of SPD

Although the exact etiology of SPD remains largely unclear, several factors have been hypothesized to contribute to its development. Studies have shown that children with a history of prematurity, low birth weight, and maternal substance use during pregnancy have a higher likelihood of developing SPD. For instance, research indicates that up to **46%** of children born before **32 weeks** of gestation exhibit sensory processing difficulties by age four [42]. The home and social environment, including caregiver behaviors, parental stress, and sensory stimulation, can impact sensory processing development. Limited sensory experiences in early childhood may lead to atypical sensory processing mechanisms [43,44]. Moreover, evidence suggests that sensory processing traits have a heritable component, implicating genetic predispositions in the manifestation of SPD [45].

2-3- Impact of SPD on Children

The impact of SPD is profound, affecting various domains of child development, including academic achievement, peer relationships, and emotional health. Children with SPD frequently experience difficulty in social interactions, motor coordination, and academic performance, leading to secondary issues such as low self-esteem, anxiety, and social withdrawal [46].

Academic settings often highlight the challenges posed by SPD. Sensory difficulties can interfere with learning and peer relationships, ultimately impairing academic achievement [47]. Furthermore, many children with SPD may face stigmatization or misunderstanding from peers and educators, exacerbating their social difficulties [36].

2-4- Assessment and Identification of SPD

Currently, assessments for SPD largely rely on behavioral observations and caregiver reports. Tools such as the **Sensory Profile (SP)** and the **Sensory Integration and Praxis Test (SIPT)** are widely used in clinical and research settings. The **Short Sensory Profile**, a condensed version of the SP, is commonly utilized due to its simplicity and reliability [41,48]. Despite the availability of these assessment tools, the reliance on subjective reports poses challenges in accurately diagnosing SPD. The absence of validated biomarkers complicates the identification process, leading to underdiagnosis in many children with sensory processing issues [49]. Recent efforts have focused on developing objective biomarkers for SPD to enhance diagnostic accuracy. Techniques such as **electroencephalography (EEG)** and **diffusion tensor imaging (DTI)** have shown promise, though more research is needed to validate their clinical relevance [50].

2-5- SPD Interventions and Treatments

Intervention strategies for children with SPD focus on improving sensory processing and enhancing functional outcomes. Occupational therapy is a common approach, employing strategies such as **sensory integration therapy**, which aims to improve the brain's ability to process sensory information through structured exposure and play [6].

Parent-implemented interventions have also demonstrated efficacy, empowering caregivers to support their children's sensory development at home [7]. Additionally, adopting a multidisciplinary approach to intervention, involving educators, therapists, and healthcare professionals, can result in better outcomes for children with SPD.

3- Methods

3-1- Study design and settings

This was a cross-sectional study conducted at Center for Developmental and Behavior Disorders from 1/9/2024 to 1/11/2024. The study was approved by Ministry of Health at Taif Health Cluster (IRB: H-02-T-123). Each parent or caregiver provided informed consent before participation of his/her child in the study.

3-2- Inclusion and exclusion criteria

The study included 83 Saudi children: 49 diagnosed with NDDs, including ADHD, autism, Down syndrome, global developmental delay, learning difficulties, and mental retardation, and 34 TD children. Children whose parents or caregivers agreed to participate were included, while those who refused were excluded. Additionally, children with non-developmental disorders were excluded.

3-3- Assessment tool

The primary assessment tool utilized in this study was the Short Sensory Profile (SSP), a 38-item standardized questionnaire designed for parents/caregivers to recognize children with sensory processing challenges and associated behaviors. Each of the 38 SSP items is rated on a 5-point Likert scale, ranging from 1 for behaviors that occur "always" to 5 for behaviors that occur "never." Composite scores for seven domains (Tactile Sensitivity, Taste/Smell Sensitivity, Movement Sensitivity, Under-Responsive/Seeks Sensation, Auditory Filtering, Low Energy/Weak, and Visual/Auditory Sensitivity) are derived from the raw scores. The SSP total score and the score on each of the instrument's seven subscales can be used to classify children into the categories of "Typical Performance," "Probable Difference," or "Definite Difference" (29). Validity and reliability studies have demonstrated the SSP's effectiveness. Initial validity assessments indicated over 95% discriminant validity in identifying children with and without sensory modulation difficulties (30). The SSP's internal reliability, measured by Cronbach's alpha, ranges from $\alpha = 0.82$– 0.89 (29). These findings affirm the SSP's credibility as a valid and reliable tool for assessing sensory processing. **(Appendix 1)**

3-4- Data collection

Data collected in the study included participants' age, gender, and NDD type. The Short Sensory Profile (SSP) (29) was utilized to assess SPD among the participants based on their caregivers' responses. This list encompasses six dimensions: sensory touch disorder (seven items), sensitivity to taste or smell (four items), sensitivity to movement (three items), weak response/sensation seeking (seven items), auditory filtering (six

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items), and low/weak energy (six items). Each of these dimensions has defined scoring thresholds, which are detailed in (**Table 1**.)

Table 1. Dimensions of short sensory list and their degrees

Dimension	Classification
First dimension	
From 7 to 26	Definite difference
From 27 to 29	Possible difference
From 30 to 35	Typical performance
Second dimension	
From 4 to 11	Definite difference
From 12 to 14	Possible difference
From 15 to 20	Typical performance
Third dimension	
From 3 to 10	Definite difference
From 11 to 12	Possible difference
From 13 to 15	Typical performance
Fourth dimension	
From 7 to 23	Definite difference
From 24 to 26	Possible difference
From 27 to 35	Typical performance
Fifth dimension	
From 6 to 19	Definite difference
From 20 to 22	Possible difference
From 23 to 30	Typical performance
Sixth dimension	
From 6 to 23	Definite difference
From 24 to 25	Possible difference
From 26 to 30	Typical performance

3-5- Statistical analysis

All statistical analyses were performed using SPSS version 26. Descriptive statistics, including frequencies and percentages, were used to summarize categorical variables. Gamma coefficients were applied to compare sensory dimensions between the two groups, as well as to assess the strength and direction of associations between gender and the ordinal sensory dimensions. Additionally, ANOVA was employed to examine associations between age

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groups and sensory dimensions within each group. All analyses were conducted with a 95% confidence interval (CI), and a p-value ≤ 0.05 was considered statistically significant.

4- Results

4-1- Clinicodemographic characteristics

The study included 83 participants, comprising 34 TD children and 49 children with NDDs. Among these disorders, ADHD was the most common diagnosis (25.3%), followed by autism (15.7%), while Down syndrome and learning difficulties were the least common, each accounting for 1.2% of the sample. The participants were distributed across three age groups: 3-5 years (32.5%), 6-10 years (35%), and 11-14 years (32.5%). Female participants made up 41% of the sample **(Table 2)**.

Table 2: Clinicodemographic characteristics of the study participants (N = 83)

<table>
<tr><th colspan="2">Variable</th><th>Frequency</th><th>Percentage</th></tr>
<tr><td rowspan="3">Age</td><td>3-5 years</td><td>27</td><td>32.5%</td></tr>
<tr><td>6-10 years</td><td>29</td><td>35%</td></tr>
<tr><td>11-14 years</td><td>27</td><td>32.5%</td></tr>
<tr><td rowspan="2">Sex</td><td>Female</td><td>34</td><td>41%</td></tr>
<tr><td>Male</td><td>49</td><td>59%</td></tr>
<tr><td rowspan="7">NDD</td><td>None</td><td>34</td><td>41%</td></tr>
<tr><td>ADHD</td><td>21</td><td>25.3%</td></tr>
<tr><td>Autism</td><td>13</td><td>15.7%</td></tr>
<tr><td>Global developmental delay</td><td>8</td><td>9.6%</td></tr>
<tr><td>Mental retardation</td><td>5</td><td>6.0%</td></tr>
<tr><td>Down syndrome</td><td>1</td><td>1.2%</td></tr>
<tr><td>Learning difficulties</td><td>1</td><td>1.2%</td></tr>
</table>

NDD: neurodevelopmental disorder; ADHD: attention deficit hyperactivity disorder

The distribution of participants by age and sex is summarized in **Table 3**. Among TD children, there was an equal distribution of males and females (50.0% each). The majority of TD children were aged 3-5 years (41.2%), followed by equal proportions aged 6-10 years and 11-14 years (29.4% each). In contrast, among children with developmental disorders, males were predominant (65.3%). The largest age group for children with developmental disorders was 6-10 years (38.8%), followed by those aged 11-14 years (34.7%) and 3-5 years (26.5%).

Table 3: Distribution of the study participants (N = 83) according to their age and sex

<table>
<tr><th colspan="2" rowspan="2">Variable</th><th colspan="2">NDD</th></tr>
<tr><th>No
(N = 34)</th><th>Yes
(N = 49)</th></tr>
<tr><td rowspan="3">Age</td><td>3-5 years</td><td>41.2%</td><td>26.5%</td></tr>
<tr><td>6-10 years</td><td>29.4%</td><td>38.8%</td></tr>
<tr><td>11-14 years</td><td>29.4%</td><td>34.7%</td></tr>
<tr><td rowspan="2">Sex</td><td>Female</td><td>50.0%</td><td>34.7%</td></tr>
<tr><td>Male</td><td>50.0%</td><td>65.3%</td></tr>
</table>

NDD: neurodevelopmental disorder

4-2- Sensory processing profiles

Children with NDDs demonstrated significantly higher rates of sensory processing challenges compared to TD children across multiple dimensions **(Table 4)**. For **tactile sensitivity**, 65.3% of children with NDDs exhibited definite difference, compared to 35.3% of TD children, while 61.8% of TD children showed typical performance. In **movement sensitivity**, 44.9% of children with NDDs had definite difference, compared to 14.7% of TD children, with most TD children (61.8%) showing typical performance. For **under-responsiveness/seeks sensation**, 69.4% of children with NDDs had definite difference, while 67.6% of TD children displayed typical performance.

In **auditory filtering**, 55.1% of children with NDDs showed definite difference, compared to 11.8% of TD children, with 79.4% of TD children demonstrating typical performance. In **low energy/weak sensitivity**, 57.1% of children with NDDs exhibited definite difference, compared to 29.4% of TD children, who mostly had typical performance (61.8%). For **taste/smell sensitivity**, while 38.8% of children with NDDs had definite difference, 79.4% of TD children exhibited typical performance.

Table 4: Comparison of sensory processing profiles between TD children (N = 34) and those with NDDs (N = 49)

Dimension		NDD		Total
		No (N = 34)	Yes (N = 49)	
Tactile sensitivity	Definite difference	35.3%	65.3%	53.0%
	Possible difference	2.9%	20.4%	13.3%
	Typical performance	61.8%	14.3%	33.7%
Taste/smell sensitivity	Definite difference	8.8%	38.8%	26.5%
	Possible difference	11.8%	16.3%	14.5%
	Typical performance	79.4%	44.9%	59.0%
Movement sensitivity	Definite difference	14.7%	44.9%	32.5%
	Possible difference	23.5%	26.5%	25.3%
	Typical performance	61.8%	28.6%	42.2%
Under-responsive/seeks sensation	Definite difference	20.6%	69.4%	49.4%
	Possible difference	11.8%	12.2%	12.0%
	Typical performance	67.6%	18.4%	38.6%
Auditory filtering	Definite difference	11.8%	55.1%	37.3%
	Possible difference	8.8%	18.4%	14.5%
	Typical performance	79.4%	26.5%	48.2%
Low energy/weak	Definite difference	29.4%	57.1%	45.8%
	Possible difference	8.8%	10.2%	9.6%
	Typical performance	61.8%	32.7%	44.6%

Comparison of sensory dimensions across both groups revealed significant negative associations were observed across all dimensions, indicating that children with NDDs were more likely to exhibit definite differences in sensory

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processing compared to TD children. The strongest associations were in auditory filtering (gamma = -0.785, *p* = 0.0005) and under-responsiveness/seeks sensation (gamma = -0.764, *p* = 0.0005), suggesting these are key areas of sensory challenges for children with NDDs. Other dimensions, such as tactile sensitivity (gamma = -0.625, *p* = 0.0005), taste/smell sensitivity (gamma = -0.638, *p* = 0.0005), and movement sensitivity (gamma = -0.573, *p* = 0.0005), also showed significant negative associations, reflecting consistent sensory deficits in these areas. The weakest association was observed in low energy/weak sensitivity (gamma = -0.501, *p* = 0.005), although it was still statistically significant **(Table 5)**.

Table 5: Comparison between TD children (N = 34) and those with NDDs (N = 49) regarding different dimensions using gamma coefficients

Dimension	Gamma	p-value
Tactile sensitivity	-0.625	**0.0005***
Taste/smell sensitivity	-0.638	**0.0005***
Movement sensitivity	-0.573	**0.0005***
Under responsive/ seeks sensation	-0.764	**0.0005***
Auditory filtering	-0.785	**0.0005***
Low energy/ weak	-0.501	**0.005***

**: statistically significant*

4-3- Effects of age and sex on sensory dimensions

ANOVA analysis revealed no significant effect of age on most sensory dimensions for the study groups. However, a significant age-related effect was observed in the under-responsive/seeks sensation dimension for children with NDDs (p = 0.045) **(Table 6)**. This suggests that while sensory processing remains largely consistent across age groups, sensory seeking behaviors may vary with age in children with NDDs, warranting further investigation and potential age-specific interventions.

Table 6: Effect of age on different sensory dimensions in TD children (N = 34) and those with developmental disorders (N = 49)

Dimension	NDD	
	No (N = 34)	Yes (N = 49)
Tactile sensitivity	0.560	0.934
Taste/smell sensitivity	0.679	0.693
Movement sensitivity	0.735	0.856
Under responsive/ seeks sensation	0.68	**0.045***
Auditory filtering	0.4	0.116
Low energy/ weak	0.929	0.797

*NDD: neurodevelopmental disorder; *: statistically significant*

Among TD children, a significant gender effect was observed for movement sensitivity (p = 0.047), whereas other dimensions showed no significant associations. In children with NDDs, gender had a significant effect on taste/smell sensitivity (p = 0.036), while other dimensions did not show significant differences **(Table 7)**. These findings suggest the presence of gender-related sensory variations in specific dimensions, which may be relevant for developing tailored sensory interventions.

Table 7: Effect of gender on different sensory dimensions in TD children (N = 34) and those with NDDs (N = 49)

Dimension	NDD	
	No (N = 34)	Yes (N = 49)
Tactile sensitivity	0.338	0.053
Taste/smell sensitivity	0.636	**0.036***
Movement sensitivity	**0.047***	0.312
Under responsive/ seeks sensation	0.216	0.159
Auditory filtering	0.185	0.779
Low energy/ weak	0.61	0.525

*NDD: neurodevelopmental disorder; *: statistically significant*

5- Discussion

Sensory processing challenges are a defining feature of many NDDs, including ASD and ADHD. These challenges manifest in various ways, such as hypersensitivity, under-responsiveness, and sensory-seeking behaviors, impacting a child's daily functioning, social interactions, and learning. This study examined sensory processing differences between TD children and those diagnosed with NDDs using the SSP. Among 83 participants, comprising 49 children with NDDs and 34 TD children, significantly higher rates of sensory processing challenges were observed in the NDD group. Key areas of difficulty included **auditory filtering** and **under-responsiveness/seeks sensation**. Gender and age-related variations were also identified, with males showing greater deficits in taste/smell sensitivity and sensory-seeking behaviors varying across age groups. These findings provide a comprehensive understanding of sensory profiles in children with NDDs, offering insights for tailored interventions.

The results of this study align closely with prior research on sensory processing challenges in children with NDDs. For example, a study in Nepal reported heightened sensory impairments in children with ASD, with auditory filtering and sensory seeking among the most affected dimensions (31). Similarly, Al-Heizan et al. in Saudi Arabia observed significant sensory deficits in children with ASD, particularly in auditory filtering (73.9%) and under-responsiveness/seeks sensation (89.13%) (28). The overlap in findings reinforces the utility of the SSP as a reliable tool for identifying sensory difficulties and provides further evidence of sensory challenges as a hallmark feature of NDDs.

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This study highlights the prominence of auditory filtering and under-responsiveness/seeks sensation as critical dimensions of sensory dysfunction, a finding corroborated by cluster analyses in ASD populations (32). Impairment of these sensations may be due to Saudi Arabia's environmental and educational settings, often characterized by structured classroom environments with a focus on auditory learning. The rigid structure and expectations in such settings can intensify sensory-related difficulties, making them more apparent to caregivers and educators.

Interestingly, the current study observed a statistically significant age effect on sensory seeking behaviors, suggesting developmental trends in sensory processing. Prior research, such as the ELENA cohort study, similarly noted consistent sensory difficulties across age groups in children with ASD and ADHD (33). This finding aligns with previous research indicating that as children with NDDs grow, their sensory processing patterns may evolve, potentially reflecting neurological maturation or adaptive changes influenced by environmental factors (23). However, the specific evolution of sensory behaviors with age warrants further investigation. This underscores the importance of longitudinal studies to better understand the developmental trajectory of sensory challenges.

Gender norms, deeply rooted in Saudi culture, may also influence the presentation and reporting of sensory processing challenges. For example, the finding that males with NDDs exhibited greater taste/smell sensitivity deficits may reflect societal expectations of male behaviors, where deviations from cultural norms of self-control and resilience may be more scrutinized. This aligns with previous observations of subtle gender-specific trends in sensory profiles across different cultural settings (34). This highlights the need for further exploration into gender-specific sensory challenges, which could enhance the personalization of therapeutic interventions.

Cultural and contextual factors in Saudi Arabia also play a significant role in shaping sensory profiles, as highlighted by differences observed in studies conducted in various regions. For instance, variations in caregiver-reported sensory processing behaviors across cultural contexts suggest that environmental influences and caregiver expectations may impact sensory outcomes (28, 35). This underscores the importance of developing culturally sensitive assessments and interventions tailored to the unique needs of diverse populations.

The findings of this study have significant clinical implications. The high prevalence of sensory challenges, particularly in auditory filtering and sensory seeking behaviors, calls for targeted interventions that address these dimensions. Multimodal therapies integrating auditory integration and proprioceptive-based activities could prove particularly effective. Additionally, the observed age and gender-related variations suggest that interventions should be customized based on demographic characteristics to optimize outcomes. For example, programs could focus on sensory seeking behaviors in younger children and address taste/smell sensitivity in male children with NDDs.

Finally, the diagnostic utility of the SSP is reinforced by this study, highlighting its potential in identifying sensory subgroups within NDD populations. Strong associations between sensory dimensions and specific neurodevelopmental conditions suggest that the SSP could serve as a valuable tool in differential diagnosis, particularly in distinguishing between ASD and ADHD. These findings align with prior research advocating for the use of sensory profiles in refining diagnostic criteria and tailoring interventions (32).

Overall, this study contributes to the growing body of evidence documenting SPD in children with NDDs. By

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elucidating key sensory dimensions, age-related trends, and gender-specific patterns, it provides a foundation for developing personalized, evidence-based interventions. The findings emphasize the need for culturally sensitive approaches and further research into the developmental trajectory of sensory processing challenges to enhance diagnostic precision and therapeutic outcomes for affected children.

The limitations of this study should be acknowledged. First, the sample size, while sufficient to detect group differences, may limit the generalizability of the findings, particularly for rarer conditions such as Down syndrome and learning difficulties, which accounted for only a small proportion of the sample. Future research should aim to include larger and more diverse samples to enhance the robustness and applicability of the findings.

Second, the reliance on caregiver-reported data through the SSP, while valuable, introduces potential biases related to caregiver perceptions and reporting accuracy. Incorporating objective measures such as neurophysiological assessments, including visual and auditory-evoked potentials, could complement the subjective data and provide a more comprehensive understanding of sensory processing in NDDs.

Conclusion

This study highlights significant sensory processing challenges in children with NDDs compared to typically developing TD children, with key deficits observed in auditory filtering and under-responsiveness/seeks sensation. Age-related variations in sensory seeking behaviors and gender-specific differences in taste/smell sensitivity emphasize the need for tailored, demographic-specific interventions. Furthermore, the study underscores the influence of cultural and environmental factors, necessitating culturally sensitive assessment tools and intervention strategies to address the unique needs of children within diverse settings.

The high prevalence of sensory challenges, particularly in auditory filtering and sensory seeking behaviors, calls for multimodal therapies that address these dimensions and incorporate age- and gender-appropriate strategies.

While this study improves understanding of sensory processing in NDDs, its limitations such as sample size, reliance on caregiver-reported data, and the cross-sectional design call for future research. Larger, more diverse samples are needed to enhance generalizability, particularly for less common conditions like Down syndrome and learning difficulties. The integration of objective measures, such as neurophysiological assessments, could complement caregiver-reported data and provide a more comprehensive picture of sensory processing. Additionally, longitudinal research is essential to explore the developmental trajectory of sensory challenges and their interaction with other developmental and psychosocial factors.

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