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EXPLORING THE HIERARCHY OF SENSORY MODULATION: A STRUCTURED LOOK WITHIN AND ACROSS CATEGORIES

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Abstract
The ability to understand, modulate, and respond to sensory information is called sensory Processing. It is crucial for the smooth functioning and performance of daily living activities of children. This study aimed to investigate the prevalence and hierarchy of sensory modulation patterns and evaluate sensory domains regarding hypersensitivity, hyposensitivity, and sensory craving. A quantitative research approach using a survey method was implemented to examine the occurrence of sensory issues among a varied group of children. Therapists of children diagnosed with Sensory Processing Disorder were asked to provide data on a 5-point Likert scale across five categories: tactile, olfactory, oral, auditory, visual, and vestibular. The developed tool, Sensory Dysfunction Inventory (SDI) scale, was validated by three relevant experts, with the collected data showing a high reliability coefficient of .933. The Sensory Dysfunction Inventory (SDI) scale, designed to assess the presence and degree of a child's hypersensitivity, hyposensitivity, and their ability to perceive and discriminate sensory information. The sample consisted of 126 children, with girls making up a smaller portion (n=36, 18.6%) than boys (n=90, 81.4%). The tactile domain was reported as highest, with a mean of 40.48, in the context of occurrence among children with Sensory Processing disorder. The results of the study demand an individualized and therapeutic plan.

INTRODUCTION

Sensory processing is related to human behavior, cognition, and functional functioning and involves the way a nervous system obtains, integrates, and responds to sensory input received from the environment (Dunn, 1997). When differences in patterns of sensory processing occur, sensory modulation problems may occur. They are usually classified as three subtypes: hyper-responsivity, hypo-responsivity, and sensory craving (Miller et al., 2007). Atypical patterns of sensory processing are particularly relevant in neurodevelopmental disorders, including Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and Sensory Processing Disorder (SPD) (Ben-Sasson et al., 2009; Tavassoli et al., 2014).

Sensory hyper-responsivity or sensory sensitivity includes an excessive response to sensory stimuli, such as sensory discomfort from loud noises or bright lighting, or sensitivity to any of several textures (Baranek et al., 2006). Individuals who respond to sensory stimuli excessively will experience sensory overload (seek avoidance behaviors, such as

avoidance of unpleasant smells or tastes) and emotional stress (Green et al., 2015). Sensory hypo-responsivity relates to low reactions to sensory input, with individuals displaying an indifferent response to pain, temperature, or sound (Lane et al., 2010). Sensory craving is an uncommon but distinct sensory modulation pattern that relates to intense long-term desire for stimulation of the senses, often manifested by repetitive behavior, such as physical strain due to intense movement, touch, or auditory stimulation (Pfeiffer et al., 2018).

The inability to comprehend sensory information may lead to many problems in daily living, interpersonal skills, and adaptive functioning. A child who has visual hypersensitivity may experience discomfort or distress from bright or flickering lights, while a child with tactile hyposensitivity is likely to seek unusual textures to get enough sensory stimulation. In addition to having visual and tactile problems, children may also have auditory hypersensitivity (react strongly to loud sounds or noises that are unpredictable), vestibular hyposensitivity (demand excess movements like spinning or jumping). Additionally, the difficulty with feeding could be due to oral sensory issues, where certain textures and temperatures in food become unpleasant, not necessarily due to emotional neglect or parental supervision. According to Mushtaq (2024), children with sensory processing disorders often have higher responsiveness to multiple areas, including visual, auditory, tactile, vestibular, proprioceptive, and oral. All these domains play an important role in shaping the behavior and perceiving the environment.

In the clinical and educational setup, understanding the sensory modulation patterns is essential for developing targeted interventions (Schaaf et al., 2015). The presence of sensory hyper- and hypo-responses is reported to cause problems in the regulation of emotions, anxiety, and social withdrawal (Mazurek et al., 2013). Unaddressed sensory craving may lead to implications for learning and adaptability (Little et al., 2019). As awareness of sensory processing differences in neurodivergent populations grows, advocates for evidence-based assessment and interventions.

This study aims to explore sensory hyper-responsivity, hypo-responsivity, and craving patterns in children who experience difficulties with sensory processing. To better understand the hierarchy within and across different sensory domains, we aim to explore ways to develop more targeted therapeutic interventions for improved functional outcomes.

Objectives of the Study:

The objectives of the study were to explore the occurrence and hierarchy of sensory modulation patterns and to assess sensory domains in the context of hypersensitivity, hyposensitivity, and sensory craving.

Research Design and Methodology:

The study was quantitative, utilizing a survey method to investigate the prevalence of sensory issues among a diverse group of children.

Population and Sample of the Study:

Data collection focused on centers serving children with developmental disabilities in Lahore, Punjab, Pakistan. Therapists working with children diagnosed with Sensory Processing Disorder provided data using a 5-point Likert scale across five categories: tactile, olfactory, oral, auditory, visual, and vestibular (Smith et al., 2012). The sample consisted of 126 children, with girls representing a smaller portion (n=36, 18.6%) and boys the majority (n=90, 81.4%).

Instrument of the Study:

The instrument was a self-developed tool called the Sensory Dysfunction Inventory (SDI) scale, designed to assess the presence and severity of sensory sensitivities, including hyper- and hypo-sensitivity, poor perception, and discrimination. This scale was validated by three experts, yielding a high reliability coefficient of .933.

Sample of the Study:

Gender	Frequency	Percentage
Male	90	81.4%
Female	36	18.6%
Total	**126**	**100%**

The table presented the gender distribution of a randomly selected sample of the study, that 90 boys, a majority, representing 81.4 % and 36 girls, representing 18.6 %.

Mean and S.D. of Sensory Dysfunction Inventory:

Domains	Mean	S.D.
Tactile	40.268	11.321
Auditory	22.245	8.423
Visual	22.315	7.682
Vestibular	39.194	10.545
Olfactory	38.683	11.216
ORAL	22.321	8.567

The table presents the descriptive statistics for the data. The Tactile domain shows the highest mean value at 40.268, with a standard deviation (S.D.) of 11.321. The Vestibular domains have a mean of 39.194 and an S.D. of 10.545. The Olfactory domain reports a mean value of 38.683 and an S.D. of 11.216. The Oral domain has a mean of 22.321 and an S.D. of 8.567. The Auditory domain shows a mean value of 22.245 with an S.D. of 8.423. Lastly, the Visual domain reports a mean of 22.315 and an S.D. of 7.682.

Results of Sensory Dysfunction Inventory:

Sr. No.	Statement	Mean	S.D.	Min.	Max
	Vestibular and Proprioceptive Dysfunction				
	Hypersensitivity to Movement				
1	VPD Hyper 1	2.23	1.501	1.0	5.0

2	VPD Hyper 2	3.57	1.487	1.0	5.0
3	VPD Hyper 3	3.03	1.650	1.0	5.0
4	VPD Hyper 4	2.33	1.398	1.0	5.0
5	VPD Hyper 5	2.87	1.717	1.0	5.0
	Average Mean	**2.00**			
	Hyposensitivity to Movement				
6	VPD Hypo 1	3.20	1.684	1.0	5.0
7	VPD Hypo 2	2.13	1.525	1.0	5.0
8	VPD Hypo 3	2.33	1.516	1.0	5.0
9	VPD Hypo 4	2.17	1.315	1.0	5.0
10	VPD Hypo 5	2.60	1.404	1.0	5.0
	Average Mean	**2.48**			
	Poor Muscle Tone and Coordination				
11	VP. Coordination 1	2.23	1.431	1.0	5.0
12	VP Coordination 2	2.50	1.776	1.0	5.0
13	VP Coordination 3	3.20	1.373	1.0	5.0
14	VP Coordination 4	2.57	1.501	1.0	5.0
15	VP Coordination 5	2.30	1.264	1.0	5.0
	Average Mean	**2.56**			

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The table presents findings regarding vestibular and proprioceptive dysfunctions related to hypersensitivity, hyposensitivity, and poor muscle tone, as well as impaired muscle coordination. A mean value of 2.56 was reported for children with low muscular tone and coordination. VP Hyposensitivity ranked as the most frequent condition after poor muscular coordination, with an average of 2.48, and Hypersensitivity ranked third with a mean value of 2.00. This is evident that the presence of both hyper-hyposensitivity can lead to low tone, weak and poor grips, impaired responses, and inadequate coordination of activities.

Sr. No.	Statement	Mean	S.D.	Min.	Max
	Tactile Dysfunction				
	Hypersensitivity to Touch				
1	Tactile Hyper 1	2.83	1.533	1.0	5.0
2	Tactile Hyper 2	2.53	1.137	1.0	5.0
3	Tactile Hyper 3	2.43	1.194	1.0	5.0
4	Tactile Hyper 4	2.60	1.329	1.0	5.0
5	Tactile Hyper 5	2.27	1.258	1.0	5.0
	Average Mean	**2.5**			
	Hyposensitivity to Touch				
6	Tactile Hypo 1	2.67	1.583	1.0	5.0
7	Tactile Hypo 2	2.70	1.088	1.0	5.0
8	Tactile Hypo 3	2.93	1.760	1.0	5.0
9	Tactile Hypo 4	2.63	1.586	1.0	5.0
10	Tactile Hypo 5	2.87	1.655	1.0	5.0
	Average Mean	**2.8**			
	Poor Tactile Perception and Discrimination				
11	Tactile Discrimination 1	2.87	1.570	1.0	5.0
12	Tactile Discrimination 2	2.23	1.165	1.0	5.0
13	Tactile Discrimination 3	2.33	1.322	1.0	5.0
14	Tactile Discrimination 4	2.43	1.357	1.0	5.0
15	Tactile Discrimination 5	2.97	1.326	1.0	5.0
	Average Mean	**2.6**			

In the Tactile domain, the mean value of 2.8 was reported for tactile hyposensitivity. A mean value of 2.6 for tactile discrimination and an average mean value of 2.5 for tactile hypersensitivity.

Sr. No.	Statement	Mean	S.D.	Min.	Max
	Oral Dysfunction				
	Oral Hypersensitivity				
1	Oral Hyper 1	2.16	1.327	1.0	5.0
2	Oral Hyper 2	2.06	1.078	1.0	5.0
3	Oral Hyper 3	2.17	1.356	1.0	5.0
4	Oral Hyper 4	2.19	1.232	1.0	5.0
	Average Mean	**2.14**			
	Oral Hyposensitivity				
5	Oral Hypo 1	2.28	1.059	1.0	5.0
6	Oral Hypo 2	2.60	1.249	1.0	5.0
7	Oral Hypo 3	2.56	1.343	1.0	5.0
8	Oral Hypo 4	3.02	1.557	1.0	5.0
9	Oral Hypo 5	3.00	1.631	1.0	5.0
	Average Mean	**2.7**			

In the Oral Domain, the average mean value of 2.7 for hypersensitivity and a mean value of 2.14 for hyposensitivity were reported.

Sr. No.	Statement	Mean	S.D.	Min.	Max
	Auditory Dysfunction				
	Auditory Hypersensitivity				

1	Auditory Hyper 1	2.15	1.419	1.0	5.0
2	Auditory Hyper 2	2.60	1.640	1.0	5.0
3	Auditory Hyper 3	2.51	1.263	1.0	5.0
4	Auditory Hyper 4	2.58	1.418	1.0	5.0
5	Auditory Hyper 5	2.12	1.100	1.0	5.0
	Average Mean	**2.4**			
	Auditory Hyposensitivity				
6	Auditory Hypo 1	2.45	1.316	1.0	5.0
7	Auditory Hypo 2	3.00	1.601	1.0	5.0
8	Auditory Hypo 3	2.29	1.345	1.0	5.0
9	Auditory Hypo 4	2.87	1.548	1.0	5.0
	Average Mean	**2.65**			

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In the auditory domain, hyposensitivity was reported as 2.65 and 2.4 for hypersensitivity.

Sr. No.	Statement	Mean	S.D.	Min.	Max
	Visual Processing Dysfunction				
	Visual Hypersensitivity				
1	Visual Hyper 1	2.95	1.533	1.0	5.0
2	Visual Hyper 2	2.58	1.393	1.0	5.0
3	Visual Hyper 3	3.19	1.613	1.0	5.0

4	Visual Hyper 4	3.09	1.642	1.0	5.0
	Average Mean	**2.95**			
	Visual Hyposensitivity				
5	Visual Hypo 1	3.17	1.646	1.0	5.0
6	Visual Hypo 2	2.50	1.665	1.0	5.0
7	Visual Hypo 3	2.47	1.281	1.0	5.0
8	Visual Hypo 4	2.15	1.538	1.0	5.0
	Average Mean	**2.6**			

Visual hypersensitivity was reported as higher, with a mean value of 2.95. Visual hyposensitivity was reported with a mean value of 2.6.

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Sr. No.	Statement	Mean	S.D.	Min.	Max
	Olfactory Dysfunction				
	Olfactory Hypersensitivity				
1	Olfactory Hyper 1	3.16	1.362	1.0	5.0
2	Olfactory Hyper 2	2.40	1.466	1.0	5.0
3	Olfactory Hyper 3	2.57	1.350	1.0	5.0
4	Olfactory Hyper 4	2.29	1.318	1.0	5.0
	Average Mean	**2.60**			
	Olfactory Hyposensitivity				
5	Olfactory Hypo 1	2.78	1.241	1.0	5.0

6	Olfactory Hypo 2	2.55	1.343	1.0	5.0
7	Olfactory Hypo 3	2.38	1.407	1.0	5.0
8	Olfactory Hypo 4	2.20	1.494	1.0	5.0
	Average Mean	**2.50**			

In the olfactory domain, the hypersensitivity was reported to be higher, with a mean value of 2.60 and 2.50 for olfactory hyposensitivity.

Discussion:

The findings indicate that dysfunction in vestibular and proprioceptive processing, notably poor muscle coordination and tone, was the most common issue identified. This aligns with previous research, which highlighted vestibular dysfunction as a primary contributor to postural and motor coordination difficulties in children facing sensory processing challenges (Mushtaq, 2022; Miller et al., 2007). In the tactile domain, tactile hyposensitivity was the most frequently reported concern, reinforcing earlier studies that suggest children with sensory modulation issues often respond inadequately to tactile stimuli, affecting their daily engagement (Pfeiffer et al., 2011). Within oral processing, oral hyposensitivity was identified as the most prevalent issue, corroborating findings that indicate oral sensory challenges can result in feeding difficulties and speech articulation problems (Smith et al., 2015). Notably, auditory hyposensitivity was also significant, supporting research that shows auditory under-responsiveness may impede language development and attention in children with sensory integration dysfunction (Tomchek & Dunn, 2007). The visual domain exhibited the highest average for visual hypersensitivity, affirming recent studies demonstrating that children with SPD often struggle with bright lights, disorganized spaces, or intense visual stimuli (Baranek et al., 2013). Overall, the pattern of hyposensitivity dominating the tactile, oral, and auditory systems, alongside hypersensitivity in the visual domain, reflects established research and underscores the necessity for targeted sensory-specific therapeutic approaches.

Conclusion &Recommendations:

The study emphasizes the prevalence and hierarchy of sensory modulation dysfunctions across different sensory areas. Notable concerns include poor tone and muscle coordination in the VPP domain, as well as hyposensitivity in tactile, oral, and auditory areas. Visual hypersensitivity also stands out as a major issue. Timely identification and intervention are essential, making early screening and assessment critical. Creating individualized intervention plans that target specific sensory processing challenges can improve the effectiveness of therapeutic strategies. Providing education and resources to parents and caregivers about sensory processing issues empowers them to employ supportive strategies at home. Promoting interdisciplinary cooperation among healthcare providers, educators, and therapists can establish comprehensive support systems for children experiencing sensory modulation dysfunctions. Additional research is necessary to analyze the long-term effects of these dysfunctions and the effectiveness of various intervention methods.

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