DOI: 10.26387/bpa.2025.00001

Sensory processing correlates with adaptive behaviors but not with symptom severity in Italian children with autism spectrum disorders

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ABSTRACT. Oltre a difficoltà di comunicazione e interazione sociale e comportamenti e interessi ripetitivi e ristretti, i disturbi dello spettro autistico (ASD) presentano sovente atipie sensoriali, il cui impatto sul fenotipo è ancora oggetto di dibattito. In questo studio, il profilo sensoriale di 76 bambini autistici italiani in età prescolare e scolare, valutato con la versione italiana del questionario *Sensory Profile – 2*, è stato correlato con la gravità dei sintomi misurati attraverso i punteggi di comparazione derivati dall'*Autism Diagnostic Observation Schedule – 2 (ADOS-2)* e con il funzionamento adattivo ricavato dalla somministrazione delle *Vineland Adaptive Behavior Scales – Second Edition (VABS-II)*. I partecipanti allo studio hanno mostrato diffuse atipie sensoriali, che non sono risultate però associate alla severità dei sintomi autistici. Invece, sono emerse correlazioni negative, da moderate a forti, tra i domini Comunicazione e Socializzazione delle VABS-II e tutti i quadranti del *Sensory Profile – 2*, ad eccezione del quadrante Evitamento. Tali risultati suggeriscono l'importanza di una valutazione precoce del profilo sensoriale per aiutare genitori e operatori sanitari a tenere in considerazione questo aspetto sia nella vita quotidiana che nel trattamento riabilitativo.

SUMMARY. Besides social communication difficulties and the presence of repetitive behaviors and restricted interests, autism spectrum disorders (ASD) often embrace sensory atypicalities. The present study aims to assess the sensory processing profile of a sample of Italian ASD children and to test its association with both their symptom severity and adaptive functioning. Parents of 76 ASD children completed the Child Sensory Profile 2 – Italian version (CSP-2) and the Vineland Adaptive Behavior Scales - Second Edition (VABS-II). Spearman correlation was calculated between the CSP-2 quadrant and section scores and the ADOS-2 Calibrated severity scores as well as between the CSP-2 quadrant and section scores and the VABS-II (Communication, Daily living skills, and Socialization standard scores). Our sample showed widespread sensory processing atypicalities. No statistically significant association emerged between sensory profile and ASD symptom severity. Instead, we highlighted a moderate to high negative association between VABS-II Communication and Socialization and all quadrants, except Avoiding. Our findings suggest the importance of an early evaluation of the sensory profile to help parents and healthcare professionals take these aspects into consideration both in daily life and in rehabilitation treatment.

Keywords: *Autism spectrum disorders, Sensory processing, Adaptive behaviors*

INTRODUCTION

Autism spectrum disorder (ASD) is a multifactorial and heterogeneous group of neurodevelopmental disorders characterized by pervasive deficits in social interactions and communication, and a repertoire of restricted and repetitive behaviors and interests (American Psychiatric Association, 2022). Data from the Centers for disease control and prevention (2023) reported that 1 in 36 children aged 8 years was diagnosed with ASD in the United States, with a male/female ratio of about 4:1 (Maenner et al., 2023). Recently, an Italian nationwide study found an overall prevalence of 13.4 ASD children per 1,000 aged 7-9 years, with a male-to-female ratio of 4.4:1 (Scattoni et al., 2023).

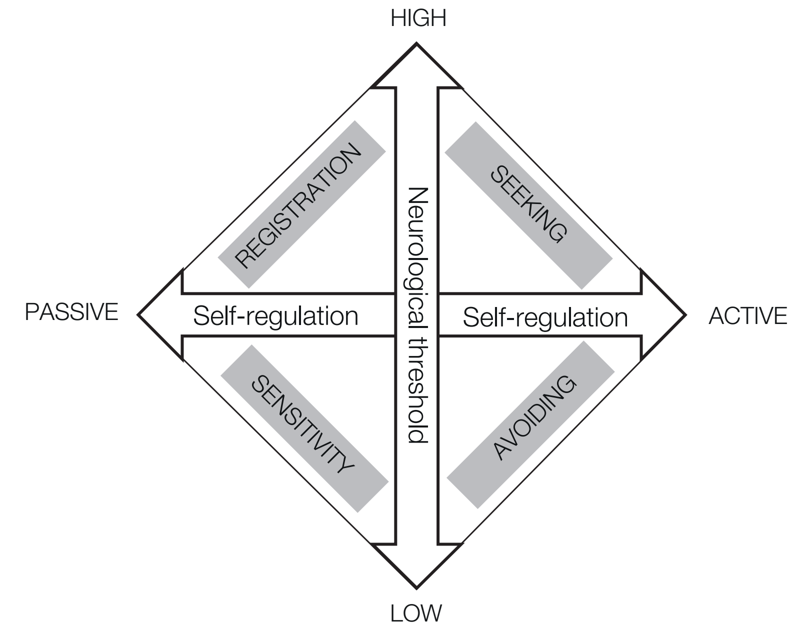
Atypical sensory processing is considered one of the earliest signs of ASD, with a prevalence between 45% and 95% of individuals, depending on the characteristics of the samples and on the evaluation procedures (Ben-Sasson et al., 2009). Starting with the *Diagnostic and statistical manual of mental disorders – Fifth edition* (*DSM-5*; American Psychiatric Association, 2013), sensory abnormalities were included in the second domain of autistic symptoms as "hyper- or hypo-reactivity to sensory input". Sensory processing refers to a multidimensional model of response to environmental stimuli, which allows the selection, modulation, integration, and organization of various types of sensory information to promote the adaptive functioning of the organism. According to Dunn's sensory processing framework (Dunn, 1999), there is an interaction between the neurological thresholds, i.e., the amount of stimuli required to elicit a neuronal activation, and the individual self-regulation, i.e., the strategies implemented in response to sensory inputs. Both these aspects vary along a continuum (see Figure 1). Specifically, neurological thresholds range from low (the nervous system is easily activated) to high (a high amount or intensity of stimuli is required to induce a neural response). As for self-regulation, the continuum spans from active responses (the individual's attempt to control their exposure to sensory stimulation) to a passive attitude (the individual does not implement any strategy to prevent hyperstimulation or to meet their high neurological thresholds). The interaction between the neurological thresholds and the self-regulation determines four patterns of sensory processing: (i) Seeking (i.e., the degree an individual obtains sensory stimuli), characterized at the extremes of the two continua by high neurological thresholds and active self-regulation; (ii) Avoiding (i.e., the degree an individual is bothered by sensory stimuli), with low neurological thresholds and active self-regulation at the extremes; (iii) Sensitivity (i.e., the degree an individual detects sensory stimuli), with low neurological thresholds and passive self-regulation at the extremes; (iv) Registration (i.e., the degree an individual misses sensory stimuli), with high neurological thresholds and passive self-regulation at the extremes. Each individual's sensory profile is characterized by a unique combination of these four patterns. Being at the extremes of one or more of these sensory patterns can impair effective participation and well-being in everyday contexts.

In individuals with ASD, unusual sensory processing is already evident in early toddlerhood and becomes more pronounced over the second year of life (Wolff et al., 2019). The sensory atypicalities occur then across all ages and can involve each sensory modality (i.e., visual, auditory, tactile, olfactory, taste, vestibular, and proprioceptive), impacting the regulation and the appropriate response to environmental stimuli (Ben-Sasson et al., 2009; Boucher, 2017). Nevertheless, a univocal ASD sensory profile has still to be defined (Leekam, Nieto, Libby, Wing, & Gould, 2007). In fact, on one hand, hypo-responsiveness was described as the most common pattern of atypical sensory processing related to behavioral challenges (Baranek, David, Poe, Stone, & Watson, 2006), while on the other hand, hyper-sensitivity was indicated as the most commonly impaired response (Ben-Sasson, Gal, Fluss, Katz-Zetler, & Cermak, 2019). Interestingly, both hypo- and hyper-responsiveness often co-occur in the same individual with ASD (Hazen, Stornelli, O'Rourke, Koesterer, & McDougle, 2014).

Moreover, only a few studies have explored the relationship between the sensory profile and ASD symptom severity. In this context, Kadlaskar et al. (2023) found that profound sensory atypicalities were associated with more significant social difficulties in autistic children, while Zachor and Ben-Itzchak (2013) even suggested that sensory abnormalities may reflect a distinct clinical phenotype with more severe autistic symptoms and lower cognitive ability. Thus, more research is needed to delve deeper into this thematic area.

Sensory abnormalities have also been investigated in relation to adaptive behaviors. In particular, Jasmin et al. (2009) demonstrated that children with ASD who adopt avoidance responses to some sensory stimuli showed greater deficits in self-care skills, such as eating and getting dressed. Moreover, ASD children with sensory-seeking or sensory-sensitivity profiles seemed to have more deficits

Figure 1 – Dunn's sensory processing framework



in communication (Lane, Young, Baker, & Angley, 2010) and in socialization skills (Tomchek, Little, & Dunn, 2015). Consistent with these findings, Dellapiazza et al. (2019) revealed that children exhibiting sensory seeking had lower adaptive scores not only in communication and socialization abilities but also in daily living and motor skills, as measured by the *Vineland Adaptive Behavior Scales – Second Edition* (*VABS-II*; Sparrow, Cicchetti, & Balla, 2005). More broadly, studies suggested that an atypical sensory profile had a negative impact on autonomy (Liss, Saulnier, Fein, & Kinsbourne, 2006), social skills (Thye, Bednarz, Herringshaw, Sartin, & Kana, 2017), and academic achievement (Ashburner, Ziviani, & Rodger, 2008). However, other studies were unable to replicate those findings (McCormick, Hepburn, Young, & Rogers, 2016). Given these conflicting results, more research is needed to better understand the relationship between atypical sensory processing and adaptive behaviors. Indeed, the characterization of the child's sensory profile could lead to more effective treatment strategies, which in turn could contribute to the subsequent development of several adaptive abilities, improving the quality of the child's present and future life.

Following this line, the purpose of the current study was twofold. The first aim was to assess the sensory processing profile in Italian ASD children using the *Child Sensory Profile 2 – Italian version,* a standardized and validated instrument. We expected to confirm widespread sensory atypicalities also in our sample.

Considering the discrepancy of results in the literature, our second aim was to assess the correlation between the sensory profile and both ASD symptom severity and adaptive behavior. We hypothesized that atypical multisensory processing in individuals with ASD could have cascading effects on their adaptive behavior and ASD symptom severity.

METHODS

This observational, cross-sectional, and multicentric study was conducted in three different Italian clinical centers (IRCCS Stella Maris Foundation, a tertiary care university Hospital, the Regional center for autism spectrum disorders, AOUI Verona, and the Observation, diagnosis and education laboratory, University of Trento) that adhered to all recommended data security and informed consent procedures, after ethics committee approval (NCT06335030).

Participants

The participant group comprised 76 children diagnosed with ASD (*M* age: 6.02 years, *SD*: 2.34; 62 males and 14 females). Inclusion criteria were: (1) children from 3 to 11 years and (2) previous clinical diagnosis of autism, established by a multidisciplinary team using a standardized process, including the ADOS-2 (Lord et al., 2012; Italian adaptation, 2013), administered by licensed and trained psychologists. Exclusion criteria were: (1) brain structural abnormalities; (2) genetic syndromes or focal neurological signs; (3) pre- or perinatal fetal distress or severe prematurity; (4) epilepsy, and (5) severe visual, auditory, and/or motor impairment.

Parents were requested to fill out the Italian version of the CSP-2 (Dunn, 2014; Italian adaptation, 2020). In addition, they were interviewed using the VABS-II (Sparrow et al., 2005; Italian adaptation, 2016), which is usually part of the clinical evaluation.

Measures

Sensory processing was assessed using the Italian version of the CSP-2. This questionnaire for caregivers of children aged 3-14:11 years contains 86 items. Parents are asked to rate their child's responses to everyday events on a five-point Likert scale. According to Dunn's sensory processing framework, scores are calculated for each sensory processing quadrant: Seeking, Avoiding, Sensitivity, and Registration. Moreover, items are organized into six sensory sections (Auditory, Visual, Touch, Movement, Body position, and Oral) and three behavioral sections (Conduct, Social-emotional, and Attentional), providing specific scores for the different sensory channels and for the behavioral aspects possibly associated with sensory processing. Scores between one and two standard deviations (*SD*) from the mean are respectively expressed as "More than others" or "Less than others". In addition, scores two *SD* or more from the mean are labeled as "Much more than others" or "Much less than others". Lower or higher SP-2 scores imply more atypical sensory patterns. Thus, these patterns result in a normal, moderately atypical, or clearly atypical profile of processing of individual sensory channels, modulation, behavior, and emotional responses (Dunn, 2014).

ASD symptom severity was established using the ADOS-2, which is a semi-structured observation considered the gold standard for assessing ASD features. Five different ADOS-2 modules are available, to be chosen based on an individual's expressive language and developmental level. The whole observation is divided into 25 to 30 items across symptom domains: social interaction, communication, repetitive and stereotyped behaviors, and play. Three scores are provided: Social affect (SA), Restricted and repetitive behaviors (RRB), and Total score. With the purpose of comparing scores across the different modules and over time, ADOS-2 calibrated scores (Calibrated severity scores - CSSs, ranging from 1 to 10) have been developed for SA, RRB, and Total score (Hus, Gotham, & Lord, 2014). Different levels of autistic symptoms correspond to different CSSs: indeed, scores 8 to 10 indicate a high level of autistic symptoms, 5 to 7 a moderate level, 3 to 4 a low level, and 1 to 2 refer to a minimum level or absence of symptoms.

Adaptive functioning was assessed using the VABS-II. This semi-structured and standardized caregiver interview of 297 items measures adaptive behaviors from childhood to adulthood (0 to 90 years old) within four domains, including multiple subdomains: Communication (Receptive, Expressive, and Written subdomains), Daily living skills (Personal, Domestic, and Community subdomains), Socialization (Interpersonal relationships, Play and leisure time and Coping skills subdomains), and Motor skills (Gross and Fine subdomains). VABS-II provides a Composite scale representative of the overall adaptive behavior level. Standard scores (*M* = 100; *SD* = 15) are available for domains and Composite scale: higher scores indicate better levels of adaptive behavior against age-related expectations. The score can be placed in a range indicating different levels of child functioning and, therefore, different levels of support needed.

Since Motor skills cannot be assessed with the VABS-II in children older than 7 years, in our study we focused on Communication, Daily living skills, and Socialization.

Data analysis

Preliminarily, the distribution of the CSP-2 and VABS-II scores and ADOS CSSs was assessed with the Shapiro-Wilk normality test.

To explore the association between sensory aspects and ASD symptom severity, Spearman correlation was calculated between the CSP-2 quadrant and section scores and the

ADOS-2 CSSs. Moreover, we grouped our participants according to the ADOS-2 symptom levels and we assessed possible differences in the CSP-2 scores using the Kruskal-Wallis test.

Spearman correlation was also computed between the CSP-2 quadrant and section scores and the VABS-II Communication, Daily living skills, and Socialization standard scores to test the relationship between sensory atypicalities and adaptive functioning.

All analyses were conducted with the R Statistical Software (v4.3.0; R Core Team, 2023), and significance levels were adjusted using the Bonferroni multiple-comparison correction.

RESULTS

For all participants (N = 76), we calculated the ADOS-2 CSSs and the CSP-2 quadrant and section scores, whereas the VABS-II scores were obtained only for 52 children.

Sensory processing profiles

As shown in Table 1, several children scored higher than 1 *SD* above the mean in the CSP-2 quadrants and sections. Considering quadrants and sections singularly, more than half of the participants scored in the *More/Much more than the others* categories in the Avoiding and Sensitivity quadrants, the Auditory section, and all three behavioral sections. Interestingly, 14% of the children were evaluated lower than 1 *SD* under the mean in the Visual section.

As for combinations of quadrant scores outside the norm, 17 participants (22.4%) had all quadrant scores in the *More/Much more* or *Less/Much less than the others* categories, whereas the second most represented quadrant combination outside the norm was Avoiding, Sensitivity and Registration (11 children, 14.5%), followed by Avoiding and Sensitivity (8 children, 10.5%), as displayed in Figure 2. To note, only 13 children (17,1%) scored in the *Just like the majority of others* category in all quadrants.

Regarding the sensory sections, 67 children (88.2 %) scored outside the norm in at least one, but only 4 participants (5.2 %) in all sections (see Figure 3). Almost half of our participants fell into the *Much/More than others* or *Much/Less than others* categories in two sensory sections (20 participants, 26,3%) or only in one (16 participants, 21,1%). In the first case, the most represented combinations were Auditory and Touch (4 children), Auditory and Visual (3 children), and Auditory and Movement (3 children). Instead, in the case of single sections, the most common were Auditory (5 children), Oral (4 children), and Visual (3 children).

Regarding the behavioral sections, the most recurring combination outside the norm was Conduct and Attention (11 children, 14.5 %), with 60 children (78.9 %) having at least 1 and 27 (35.5 %) having all behavioral section scores outside the norm (see Figure 4).

Sensory profile and ASD symptom severity

The ADOS-2 CSSs (*M* and *SD*) are reported in Table 2. Most participants showed a moderate ASD symptom level in SA and Total CSSs and a high level in RRB CSSs.

According to the Shapiro-Wilk test, the following variables were not normally distributed ($p<.05$): Registration, Visual, Touch, Movement, Body position, Oral, SA CSSs, RRB CSSs, and Total score CSSs.

The Spearman correlation between each CSP-2 score (quadrant and sensory and behavioral section scores) and each CSS showed only weak associations, with none reaching statistical significance ($p<.05$) after the Bonferroni correction (see Table 3).

Considering the broad participants' age range (3-11 years), a Spearman partial correlation was additionally run to control for the possible effect of age on the association between CSP-2 scores and CCSs. Since the previous results were substantially confirmed, age does not seem to represent a confounding variable in this association.

To further explore the relationship between the sensory profile scores and the ASD symptom severity, we tested for possible differences in the CSP-2 quadrant and section scores among our participants grouped according to their ADOS-2 symptom severity level. Since only few children fell into the minimum level (3 for SA CSSs, 1 for RRB CSSs, and none for Total score CSSs, see Table 2), they were included in the low level group for the subsequent analyses.

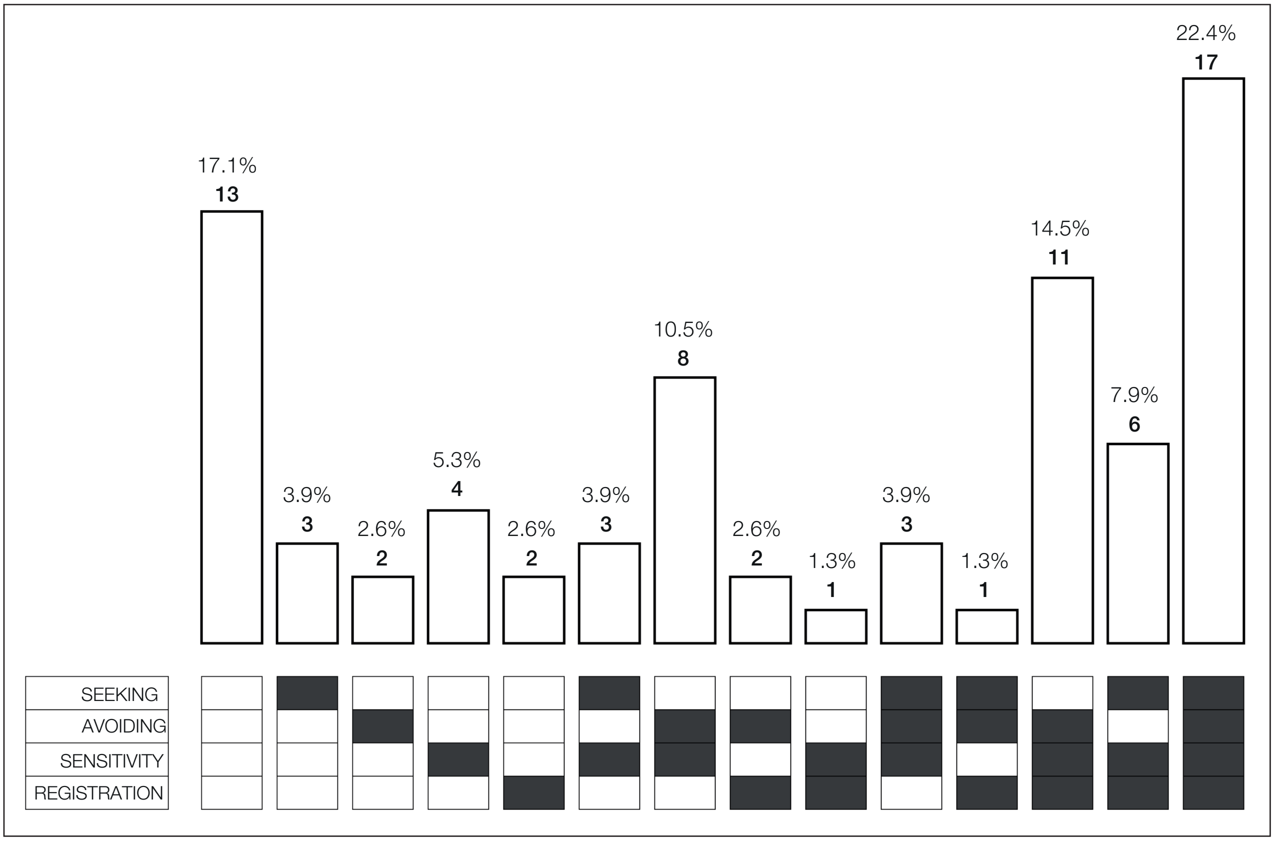
The Kruskal-Wallis test did not reveal any statistically significant difference in the CSP-2 scores between the groups with low, moderate, and high levels of symptom severity (see Table 4).

Table 1 – Percentage of children in each CSP-2 classification system category

	Much less than others	Less than others	Just like the majority of others	More than others	Much more than others
Quadrants					
Seeking	—	1.3%	56.7%	21%	21%
Avoiding	—	1.3%	42.1%	**32.9%**	**23.7%**
Sensitivity	1.3%	—	30.3%	**35.5%**	**32.9%**
Registration	2.6%	1.3%	47.4%	25%	23.7%
Sensory sections					
Auditory	—	5.3%	44.7%	**31.6%**	**18.4%**
Visual	**1.3%**	**13.2%**	64.5%	9.2%	11.8%
Touch	—	1.3%	60.5%	18.4%	19.8%
Movement	—	2.6%	57.9%	17.1%	22.4%
Body position	2.6%	1.3%	65.8%	15.8%	14.5%
Oral	—	1.3%	65.8%	17.1%	15.8%
Behavioral sections					
Conduct	—	2.6%	42.1%	**27.6%**	**27.6%**
Social emotional	—	2.6%	40.8%	**27.6%**	**28.9%**
Attentional	—	1.3%	40.8%	**25%**	**32.9%**

Note. Based on the comparison between quadrant and section scores and the Italian normative data.

Figure 2 – Combinations of CSP-2 quadrant scores outside the norm



Legenda. Bars = number of participants and percentage; black boxes = quadrants outside the norm and their combinations.

Figure 3 – Percentages of participants with CSP-2 sensory section scores outside the norm

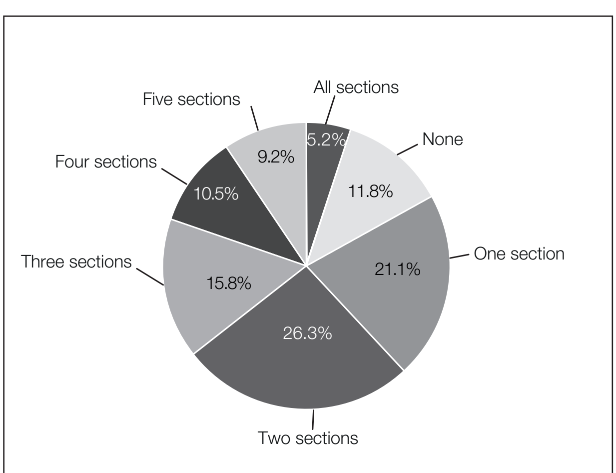


Figure 4 – Percentages of participants with CSP-2 behavioral section scores outside the norm

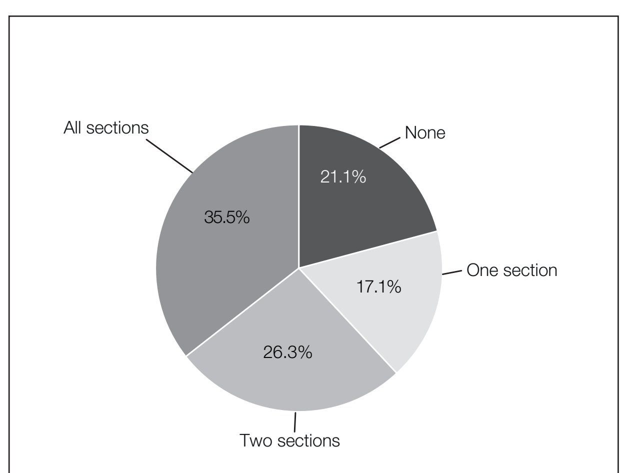


Table 2 – ADOS-2 calibrated severity scores

	CSSs		ASD symptom level		
	Mean (SD)	*Minimum (N)*	*Low (N)*	*Moderate (N)*	*High (N)*
SA	5.59 (1.76)	3	19	44	10
RRB	7.49 (1.91)	1	7	30	38
Total	5.93 (1.30)	0	14	58	4

Legenda. CSSs = Calibrated severity scores; SA = Social affect; RRB = Restricted and repetitive behaviors; N = participants with minimum, low, moderate or high symptom level.

Sensory profile and adaptive functioning

Participants obtained generally low standard scores on the VABS-II Communication (M = 62.38, SD = 18.17, Range = 28-99), Daily living skills (M = 72.48, SD = 14.63, Range = 43-111), and Socialization (M = 70.17, SD = 17.45, Range = 39-108).

As revealed by the Shapiro-Wilk test, all VABS-II domain scores were normally distributed, while several CSP-2 scores, retested in this subsample of 52 participants, followed a non-normal distribution (p<.05): Seeking, Registration, Visual, Touch, Body position, and Oral.

The Spearman correlation between the CSP-2 quadrant scores and the VABS-II domain scores showed a strong negative association between Seeking and Communication and a moderate negative association between Seeking and Socialization. Moreover, moderate negative associations were also found for both Sensitivity and Registration with Communication and Socialization. All these correlations were statistically significant after the Bonferroni correction. As regards the Avoiding quadrant, only weak and non-statistically significant correlations emerged (see Table 5).

In the sensory sections, a statistically significant moderate negative correlation was found between the Visual and Touch sections and Communication, as well as between the Touch section and Socialization.

Considering the behavioral aspects, the Conduct and Attentional sections correlated moderately with Communication, while a statistically significant negative association with Socialization was obtained only for the Attentional section.

In addition, we conducted a partial Spearman correlation to exclude a possible impact of age on the association between sensory profile and adaptive functioning. Again, the results of the previous correlation were substantially confirmed.

DISCUSSION

This study assessed the sensory processing profile in a sample of Italian children with ASD. Our results are consistent with prior findings, showing that children with ASD often exhibit differences in sensory processing patterns across all sensory modalities when compared to typically developing (TD) controls (Alsaedi, Carrington, & Watters, 2023). In fact, the majority of participants displayed high quadrant scores, particularly in the Avoiding and Sensitivity patterns, showing a low neurological threshold for the sensory stimuli, according to Dunn's Sensory processing framework (Dunn, 2014). These findings seem to be in line with some existing evidence that hypersensitivity is the most atypical response in ASD (O'Brien et al., 2009), affecting the ability to provide an adequate response to environmental stimuli and, consequently, to participate effectively in everyday life (Dunn, 2014).

Moreover, the present study revealed auditory processing to be the most affected sensory system, in line with previous studies showing auditory processing abnormalities in ASD children (Alsaedi et al., 2023; Little, Dean, Tomchek, &

Table 3 – Correlation between CSP-2 scores and ADOS-2 CCSs

	SA CSS		RRB CSS		Total CSS	
	rs	*partial rs*	*rs*	*partial rs*	*rs*	*partial rs*
Quadrants						
Seeking	.017	.027	.043	.029	.088	.086
Avoiding	.066	.024	−.019	.001	.011	.022
Sensitivity	.108	.102	.010	.004	.136	.135
Registration	.268	.223	.022	.043	.224	.231
Sensory sections						
Auditory	.181	.127	−.004	.013	.127	.113
Visual	.129	.080	−.092	−.083	.011	.004
Touch	.072	.055	.063	.063	.199	.192
Movement	.079	.084	.053	.044	.140	.140
Body position	.132	.064	−.181	−.166	−.013	−.021
Oral	−.206	−.178	.019	−.009	−.108	−.109
Behavioral sections						
Conduct	.047	.064	.028	.018	.148	.148
Social emotional	.138	.078	−.006	.023	.096	.103
Attentional	.236	.233	.094	.090	.277	.277

Legenda. rs = Spearman's rho; SA CSS = Social affect Calibrated severity score; RRB CSS = Restricted and repetitive behaviors Calibrated severity score; Total CSS = ADOS Total score Calibrate severity score.
Note. No statistically significant correlations ($p<.05$) after the Bonferroni correction.

Table 4 – Assessment of differences in CSP-2 scores between subjects grouped according to the ADOS-2 CCSs symptom levels (Kruskal-Wallis test)

	SA CSS		**RRB CSS**		**Total CSS**	
	$\chi^2(2)$	*p*-value	$\chi^2(2)$	*p*-value	$\chi^2(2)$	*p*-value
Quadrants						
Seeking	1.034	.596	1.561	.458	3.65	.161
Avoiding	.420	.810	.022	.989	1.226	.542
Sensitivity	.601	.741	2.327	.312	4.161	.125
Registration	2.316	.314	.108	.948	1.756	.416
Sensory sections						
Auditory	1.565	.457	1.723	.423	1.116	.572
Visual	4.049	.132	1.908	.385	.084	.959
Touch	.566	.753	.191	.909	3.881	.144
Movement	.890	.641	.066	.968	5.252	.062
Body position	1.103	.576	2.184	.335	.049	.976
Oral	1.024	.599	.104	.949	5.788	.055
Behavioral sections						
Conduct	1.791	.408	1.417	.493	5.204	.074
Social emotional	.137	.934	.111	.946	1.080	.583
Attentional	2.268	.322	.679	.712	3.050	.218

Legenda. SA CSS = Social affect Calibrated severity score; RRB CSS = Restricted and repetitive behaviors Calibrated severity score; Total CSS = ADOS Total score Calibrate severity score.

Table 5 – Correlation between CSP-2 scores and VABS-II Communication, Daily living skills, and Socialization scores

	Communication		**Daily living skills**		**Socialization**	
	rs	*partial rs*	*rs*	*partial rs*	*rs*	*partial rs*
Quadrants						
Seeking	−.602***	−.602***	−.205	−.203	−.411*	−.427*
Avoiding	−.269	−.281	−.244	−.249	−.332	−.293
Sensitivity	−.593***	−.582***	−.239	−.217	−.485**	−.458*
Registration	−.399*	−.422*	−.271	−.240	−.445**	−.392*
Sensory sections						
Auditory	−.386	−.381	−.228	−.203	−.355	−.323
Visual	−.448*	−.473**	−.206	−.174	−.308	−.266
Touch	−.539**	−.524**	−.292	−.265	−.518**	−.466*
Movement	−.419	−.401	−.223	−.201	−.355	−.331
Body position	−.142	−.168	−.029	−.004	−.049	.005
Oral	−.391	−.404	.007	.004	−.255	−.285
Behavioral sections						
Conduct	−.542**	−.533**	−.353	−.335	−.404	−.398
Social emotional	−.189	−.169	−.146	−.121	−.257	−.175
Attentional	−.450*	−.444*	−.239	−.216	−.433*	−.414

Legenda. rs = Spearman's rho.
Note. * p<.05, ** p<.01, *** p<.001 (after the Bonferroni correction).

Dunn, 2018). Since difficulties affecting the auditory channel can influence language development and contribute to communication difficulties in children with ASD (Marco, Hinkley, Hill, & Nagarajan, 2011), early detection is crucial for appropriate and timely interventions. It is also interesting to note that, differently from the other sensory sections, several participants in our study scored below the norm in the visual domain. Also this result represents a sensory atypicality and means that these children show the behaviors described in the CSP-2 visual section less frequently than their TD peers.

As for the CSP-2 behavioral sections, most children in our sample scored above the norm range. Considering the co-occurrence of high scores in the sensory sections, we can reasonably conclude that atypical sensory processing affects conduct, socio-emotional, and attentive behaviors. These findings are supported by previous research highlighting significant differences in the behaviors associated with sensory processing symptoms between children with and without ASD (Little et al., 2018). Indeed, sensory hypersensitivity, experienced by up to 90% of people with ASD, is considered one of the main causes of behavioral difficulties and disruptive behaviors (Tavassoli, Miller, Schoen, Nielsen, & Baron-Cohen, 2014).

The current study found a lack of correlation between the sensory profile, measured by CSP-2 scores, and ASD symptomatology, measured by ADOS-2. This result could suggest that atypical sensory responsivity is relatively independent of ASD symptom severity. However, it should also be considered that CSP-2 is a questionnaire for parents, whereas ADOS-2 is a semi-structured observation conducted by clinicians. Wolff et al. (2019) showed that parent-reported measures of sensory performance are more strongly linked with other parent-reported measures rather than clinical and observation-based measures. Moreover, Kadlaskar et al. (2023) suggested that the discrepancy between ADOS-2 and other measures of ASD symptom severity could be attributed to contextual variations in children's behaviors. Hence, parents observe their children in daily life, having the opportunity to record different aspects of the symptomatological spectrum in multiple contexts, which is not the case in the clinical evaluation. Therefore, different instruments and contexts may impact our understanding of sensory profiles and how they are linked with autism characteristics.

Nevertheless, the lack of association between sensory atypicalities and ASD symptom severity could also be traced back to some limitations of our study. In fact, the relatively small sample size might have affected the statistical significance of some analyses. In addition, for some of our participants, CSSs were calculated over the ADOS-2 scores obtained from evaluations conducted more than 12 months before the administration of the CSP-2 questionnaire. Therefore, changes in the child's profile might have occurred in this time span. Moreover, it should be considered that most participants had a medium severity level, according to the ADOS-2 total CSS. Therefore, more extreme profiles deserve to be further studied in larger samples to highlight the possible impact of sensory atypicalities on ASD symptoms in specific homogeneous subgroups.

Another aim of our study was to explore the possible association between sensory and adaptive profiles in children with ASD. We found a strong negative association between VABS-II Communication scores and Seeking and a moderate negative association between VABS-II Communication scores and both Sensitivity and Registration. This seems to be in line with previous studies showing that sensory profiles in preschoolers with ASD, particularly Seeking, affect their receptive and expressive language skills (Tomchek et al., 2015).

Our study also revealed a moderate negative association between VABS-II Socialization scores and Seeking, Sensitivity, and Registration. Previous findings have suggested a negative impact of atypical sensory processing on the socio-adaptive abilities of children with ASD, especially in understanding emotion (Thye et al., 2017), joint attention (Baranek et al., 2013), social cognition (Green et al., 2016) and empathy (Tavassoli et al., 2018). In particular, Tomchek et al. (2015) reported that ASD children with a Seeking profile had lower socialization skills and were less receptive to their social environment.

It can be hypothesized that the overload of sensory information from the environment or the difficulty of recording elements functional for socio-communicative purposes could make ASD children less receptive to the social environment and prevent them from having effective communication. Moreover, according to Cunningham and Schreibman (2008), the association between sensory processing and adaptive functioning might indicate that individuals diagnosed with ASD use socially unacceptable behaviors to regulate under-stimulation and to reinforce sensory stimuli.

Concerning the VABS-II Daily living skills, we found no significant correlation with any CSP-2 quadrants. By contrast, previous studies showed a significant association between atypical sensory processing and both daily living skills (Baker, Lane, Angley, & Young, 2008) and personal autonomy (Jasmin et al., 2009). In particular, in a study with a large sample of children aged 3 to 10 years, Dellapiazza et al. (2019) found that Seeking was associated with lower scores in all Vineland domains. In addition, a longitudinal study (Williams et al., 2018) revealed that higher parent-reported sensory hypo/hyper-responsiveness in early childhood predicted overall lower adaptive behaviors and lower daily living skills in later childhood. However, these findings are inconsistent with a recent study in which predictive factors for the adaptive functioning of individuals with ASD were intellectual quotient, age, and social symptoms rather than an atypical sensory profile (Tillmann et al., 2019).

CONCLUSION

We confirmed widespread sensory atypicalities in a sample of Italian ASD children aged 3 to 11 years assessed with the Italian version of the CSP-2. Despite the prevalence of high scores in Avoiding and Sensitivity patterns as well as in the Auditory section, a notably high variability emerged among our participants' sensory profiles. Therefore, studies with larger samples are needed to identify possible ASD-specific sensory clusters. Furthermore, longitudinal investigations would allow for studying the developmental trajectories of sensory atypicalities in individuals with ASD over time.

Our study did not reveal any association between the sensory profile and the ASD symptom severity, whereas we highlighted a possible impact of sensory atypicalities on adaptive behavior. Interestingly, initial evidence from the literature suggests the impact of cognitive level on adaptive behavior. Therefore, our results should be further replicated in future research with larger and more heterogeneous individuals in terms of symptom severity, also taking into account the possible role cognitive level plays in the relationships between sensory profile, ASD symptom severity, and adaptive functioning.

Finally, it is important to note that the ADOS-2, the gold standard for the evaluation of autistic symptoms, provides only one item dedicated to the sensory aspects. Since sensory processing alterations are a pervasive component of everyday experiences in autistic individuals, and atypical sensory patterns impact adaptive behavior, it is highly recommended to include a sensory-specific tool in the ASD assessment. In fact, it could help parents and teachers become aware of how the sensory features of the environment and everyday life experiences can compromise the child's well-being and how their modulation can promote effective participation and prevent non-functional behavior. Moreover, the early detection of sensory atypicalities could aid professionals in supporting the child's development, preventing a possible negative impact on communicative and social skills acquisition.

Acknowledge: Ilaria Basadonne and Viola Passani contributed equally to this work. **Funding:** This work has been partially supported by the Italian Ministry of Health- Grant RC (RC 2024).

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