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ORIGINAL ARTICLE

Global Sensory Features are Linked to Executive and Attentional Impairments in Autism Spectrum Disorders

Pierre Augé[1] · Anna Maruani[1,3] · Elise Humeau[1,2] · Pierre Ellul[1] · Ariane Cartigny[1,2,5] · Aline Lefebvre[1] · Florine Dellapiazza[4] · Richard Delorme[1] · Hugo Peyre[1,4]

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Abstract

Sensory features, executive and attentional impairments are frequently reported in individuals with autism spectrum disorders (ASD). However, little is known about their complex relationships. In this study, we aim to examine the executive and attentional difficulties related to distinct sensory profiles. We identified sensory profiles with a Latent Profile Analysis (LPA) based on scores on the Short Sensory Profile (SSP) questionnaire in 95 children with ASD aged 6 to 17 years. Executive and attention functions were assessed using the Behavior Rating Inventory of Executive Functions (BRIEF) questionnaire and Attention-Deficit Hyperactivity Disorder Rating Scale (ADHD-RS). A three-cluster solution based on raw SSP scores identified a "high'', a "medium" and a "low'' SSP profile. We found a significant relationship between executive functions, attentional skills and the global severity of sensory features, reinforcing findings of previous studies in the literature. A two-cluster solution based on normalized SSP (i.e. equalized for the global severity) identified distinct sensory profiles, mainly discriminated by the score of underresponsive/seeks sensation. We found no significant difference between these two clusters for the BRIEF and ADHD-RS related scores. Our study suggests that the heterogeneity of sensory features in ASD may not be explained by differences in executive and attention functions. Future studies are needed to refine the link between sensory features and executive functions in autism.

Keywords Children · Latent profile analysis · Autism · Sensory features · Executive functions

Autism Spectrum Disorders (ASD) represent complex and heterogeneous neurodevelopmental conditions characterized by impairment in social communication combined with restricted and repetitive behaviors (American Psychiatric Association, D. S., and American Psychiatric Association. Diagnostic and statistical manual of mental disorders: DSM-5. Vol. 5. Washington, DC: American psychiatric association, 2013., s. d.). Their prevalence is currently estimated at 2.2% (Christensen et al., 2019). Sensory features in autism are reported by numerous studies (Ben-Sasson et al., 2009; Ben-Sasson et al., 2019), and displayed by 45 to 90% of individuals with ASD (Ben-Sasson et al., 2009). They are present throughout the lifespan, including early childhood (Germani et al., 2014). They are therefore an early and core feature of autistic symptoms. The link between sensory impairments and high-level cognitive processes such as executive functions in autism remains a source of debates. Executive functions are defined as the high-level cognitive processes requested for the initiation, maintenance and re-evaluation of goal-directed behaviors (Stuss, 2011). They involve the selection, planning, initiation, inhibition, and re-evaluation of thoughts and behaviors (Friedman & Miyake, 2017), as well as attentional skills, which is defined by the ability to select different sensory inputs, perceptions, trains of thought or action patterns while others are masked (Talsma et al., 2010).

✉ Pierre Augé
pierre.auge2@gmail.com

1 Department of Child and Adolescent Psychiatry, Robert Debré Hospital, APHP, Paris-Cité University, Paris, France

2 Fondation FondaMental, Créteil, France

3 Centre de Référence "Déficiences Intellectuelles", Robert Debré Hospital, Paris, France

4 Centre de Ressources Autisme Languedoc-Roussillon et Centre d'Excellence sur l'Autisme et les Troubles Neurodéveloppement (CeAND), CHU Montpellier, Montpellier, France

5 Laboratory of Psychopathology and Health Process, Université Paris Cité, F92000 Paris, France

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Numerous studies report executive dysfunction in individuals with ASD (Demetriou et al., 2019) affecting 35–70% of them (Gioia et al., 2002), and impacting all the executive domains (Demetriou et al., 2018). A relationship between executive functions and sensory features is also found by several studies in ASD (Erfanian et al., 2018; Fernandez-Prieto et al., 2021; Pastor-Cerezuela et al., 2020). However, the results concerning the mutual influence of executive functions and sensory features remain conflicting (Boyd et al., 2009). These contrasting results can be explained by the heterogeneity of executive/sensory impairment in autism (Gioia et al., 2002). Some studies show impaired attentional processes (Lyall et al., 2017), which predict sensory features (Dellapiazza et al., 2018, 2021; Sanz-Cervera et al., 2015). Specifically, sensation seeking is associated with difficulties in attentional disengagement (Alateyat et al., 2022; Baranek et al., 2018; Dellapiazza et al., 2021; Sabatos-DeVito et al., 2016).

Given the extreme heterogeneity of individuals included on the autism spectrum, much work has attempted to identify distinct and more homogeneous subgroups (Ousley & Cermak, 2014). In this context, several studies have used cluster analysis, such as Latent Profile Analysis (LPA), to split their study sample according to common characteristics, particularly regarding sensory features (Ausderau et al., 2014a, 2014b; Lane et al., 2010, 2012, 2014; Liss et al., 2006; Little et al., 2017; Tomchek et al., 2018). These studies are able to consistently identify two sensory profiles based on overall intensity of sensory impairment: a group associated with minimal sensory features, and another one distinguished by the severity of the difficulties (DeBoth & Reynolds, 2017; Tillmann et al., 2020). They have also highlighted sensory profiles characterized by the predominant sensory modality impaired (Ausderau et al., 2014a, 2014b; Lane et al., 2014; Tomchek et al., 2018), or by the affective or behavioral repercussions related to the sensory features (Ausderau et al., 2014a, 2014b; Kaneko et al., 2022). Further, researchers have tried to identify behavioral and cognitive patterns associated with each sensory profile. For example, sensory profiles characterized by high overall intensity were associated with greater attentional difficulties (Tillmann et al., 2020). Employing the approach of identifying individual profiles within ASD proves to be a valuable research methodology for investigating the neuropsychological mechanisms underlying sensory disorders (Uljarević et al., 2017).

This study aims to examine the executive profiles and attentional difficulties related to each sensory profile, previously identified by an LPA. Our first objective is to replicate the results of clustering studies on the sensory profile in ASD. The second objective is to explore the pattern of executive and attentional impairments associated with these profiles.

Material and Methods

Participants

Our study included 95 children (74/21 male/female), aged 6 to 17 years old, from diagnostic assessments in a tertiary care facility (Table 1). Final diagnosis of ASD was based on the DSM 5 criteria (American Psychiatric Association, D. S., and American Psychiatric Association. Diagnostic

Table 1 Characteristics of the study population and clusters identified in LPA on raw data and normalized data

		Whole population	LPA on raw data				LPA on normalized data		
			Cluster 1	Cluster 2	Cluster 3	p-value	Cluster 1	Cluster 2	p-value
Number of subjects		95	10	49	36		73	22	
Age at inclusion (years)		11.1 (±2.6)	11.2 (±2.8)	10.7 (±2.7)	11.5 (±2.5)	0.43	11.2 (±2.6)	11.2 (±2.7)	0.84
% male		77.9	70.0	89.8	63.9	0.01	76.7	81.8	0.83
IQ	mean	103.5 (±17.5)	102.5 (±19.9)	103.8 (±16.8)	103.3 (±18.3)	0.98	104.1 (±17.5)	101.1 (±17.8)	0.48
	IQ < 70	3 (4%)	0 (0%)	2 (4%)	1 (3%)	0.77	2 (3%)	1 (5%)	0.85
	IQ 70–85	11 (12%)	2 (20%)	4 (8%)	5 (14%)		9 (12%)	2 (9%)	
	IQ > 85	81 (84%)	8 (80%)	43 (88%)	30 (83%)		62 (85%)	19 (86%)	
ADI-R total score		26.6 (±9.1)	21.0 (±13.4)	26.4 (±8.4)	28.6 (±8.0)	0.66	27.4 (±7.7)	24.1 (±12.5)	0.70
ADOS-2 total score		11.6 (±4.5)	8.8 (±3.5)	12.1 (±4.9)	11.6 (±4.1)	0.36	12.1 (±4.3)	10.0 (±5.0)	0.15
BRIEF total score		158.5 (±24.4)	138.9 (±26.8)	153.0 (±21.6)	171.4 (±21.3)	< 0.001	158.2 (±24.6)	158.2 (±24.2)	1
SSP total score		136.4 (±28.1)	175.3 (±6.73)	150.4 (±10.2)	106.7 (±18.9)	< 0.001	131.3 (±25.8)	153.4 (±29.6)	< 0.001
ADHD RS 5th total score		26.5 (±12.1)	18.7 (±8.1)	24.6 (±11.6)	31.2 (±11.9)	0.01	26.8 (±12.8)	25.6 (±9.6)	0.69

LPA Latent profil analysis, *IQ* intelligence quotient, *ADI-R* autism diagnostic interview-revised, *ADOS-2* autism diagnostic observation schedule-2, *BRIEF* behavior rating inventory of executive function, *SSP* short sensory profile, *ADHD-RS 5th* attention deficit/hyperactivity disorder, 5th edition and statistical manual of mental disorders: DSM-5. Vol. 5. Washington, DC: American psychiatric association, 2013., s. d.) and made by summing the information from the Autism Diagnostic Interview-Revised (ADI-R) (Rutter et al., 2003), the Autism Diagnostic Observation Schedule—2nd version (ADOS-2) (Lord et al., 2000) and data from clinical reports from experts in the field.

Measures

The Short Sensory Profile (SSP) is a parent questionnaire designed for children aged from 3 to 15 years old (McIntosh et al., 1999). It is composed of 38 items, rated according to a Likert scale of 1 to 5 which represents the frequency of the target phenomenon (1 = always, 5 = never). The symptomatic intensity is inversely proportional to the scores obtained. These items are merged into seven scores (Tactile Sensitivity, Taste/Smell Sensitivity, Auditory Filtering, Movement Sensitivity, Visual/Auditory Sensitivity, Underresponsive/Seeks Sensation, Low Energy/Weak) and a global score, which is the sum of the sub-scores.

The Behavior Rating Inventory of Executive Functions [BRIEF, (Gioia et al., 2000)] is a questionnaire designed for parents or teachers of children aged 5 to 18 years. It is composed of 86 items grouped into 8 factors, the addition of which results in two composite scores: Behavioral Regulation (Inhibit, Shift and Emotional Control) and Metacognition (Initiate, Working Memory, Plan/Organize, Organization of Material and Monitor). The addition of these composite scores gives a global score (Global Executive Composite). The parent questionnaire, used in our study, has significant reliability (Cronbach's alpha = 0.8–0.98) and test–retest reproducibility (r = 0.8).

Symptomatology associated with Attention Deficit Hyperactivity Disorder (ADHD) was assessed by the ADHD-RS 5th edition (DuPaul et al., 2016), a parent questionnaire divided into two sub-scores, one measuring inattention symptoms and the other targeting impulsivity and hyperactivity symptoms, as well as a total score resulting from the addition of both sub-scores.

Global cognitive abilities of each individual enrolled in the study was measured using the Wechsler Intelligence Scales adapted to his/her chronological age. Most were individuals with ASD without associated intellectual delay (96% with an IQ > 70).

Statistical analysis

Statistical analysis was performed with the R software (R Core Team, 2022). Prior to the LPA, a screening was conducted to check for outliers with the Grubbs test, and normality of the distribution with the Kolmogorov–Smirnov test. We removed all individuals with missing data for the different SSP scores, as the LPA requires complete data on the input variables. There was no missing data on BRIEF scores. The distribution of the variables was normal with the exception of the Taste/Smell Sensitivity ($p = 0.002$) and Movement Sensitivity ($p < 0.001$) scores of the SSP, and Organization of Material ($p = 0.004$) score of the BRIEF. Subsequently, we used non-parametric tests for subsequent analyses.

We performed LPA using the "Mclust" package (Scrucca et al., 2016). LPA is a form of mixture model used to identify homogeneous sub-groups from pre-defined continuous variables. It allows to obtain, for each individual according to their characteristics, an a posteriori probability of belonging to the different identified clusters. In our study, we selected as input variable the Z-score of the seven scores of the SSP. We estimated the solutions from the 14 statistical models included in the Mclust package.

The LPA leads to several solutions, different by the number of clusters and the types of statistical models. We selected the most faithful solution based on the Bayesian Information Criterion (BIC), which is the most appropriate parameter, compared to the Akaike information Criteria (AIC) (Nylund et al., 2007). We also evaluated, in the process of selecting the most relevant model, the number of clusters identified as well as the number of subjects included in each cluster. We excluded solutions where the number of subjects per cluster was less than ten in order to maximize the validity of subsequent statistical analyses. We also evaluated the associated uncertainty, an important indicator of the quality of the selected model. We used the Lo-Mendell Rubin (LMR) test to determine the relevance of adding an additional cluster. Finally, we evaluated a posteriori probabilities of cluster membership for each individual. In order to avoid the global severity of sensory features, we performed a second LPA, with the normalized scores of the different scores of the SSP according to the formula:

$$\text{Normalized score} = \text{Raw score} - (\text{Total score} \times (\text{number of score items/total number of items}))$$

In a second step, we performed linear regressions between the identified clusters. We first selected the global score of the BRIEF as the dependent variable, then the two composite scores (Metacognition and Behavioral Regulation) and finally the eight executive scores. We selected as independent variables the different clusters identified. We systematically included age, gender and IQ as covariates. We assessed each model for homoscedasticity, collinearity, normality, as well as the absence of outliers in the models' residuals. All our results are corrected with the Bonferroni method. We then performed post-hoc tests of comparisons between clusters by comparing estimated marginal means.

In a third step, we evaluated the differences in global autistic symptom intensity, measured by the ADI-R and ADOS-2, and ADHD symptomatology, measured by the ADHD-RS, between the different clusters. We performed linear regressions with the total score and subscores as dependent variables, the clusters as independent variables and age, gender and IQ as covariates.

We performed an ANOVA to assess age differences between clusters, a $\chi 2$ test to assess differences in gender distribution, and a linear regression to assess differences in IQ, with age and gender as covariates. We finally categorized IQ into 3 groups (<70, 70–85 and >85) and performed a $\chi 2$ test to assess differences in their distribution.

Results

Analysis on Raw Data

The LPA on raw data revealed an optimal three-cluster solution (spherical model with unequal volumes, BIC = − 1.724, ICL = − 1.733, Log-likelihood = − 803, df = 26). The mean uncertainty was 0.04. The identified clusters grouped 10, 49 and 36 patients respectively. This first LPA revealed a classification according to a severity profile, homogeneous on all the SSP scores (Fig. 1A) and SSP total score (Fig. 1B).

We found a global and homogeneous difference in all the executive functions related scores, more marked for the shift and organization of materials scores (Fig. 1C). Cluster 1 was characterized by a lower mean score than all other executive scores. An opposite pattern was found for cluster 3. Cluster 2 represents an intermediate pattern. The highest BRIEF score (thus the most executive impairment) was found in the cluster corresponding to the lowest SSP score (thus the highest symptomatic intensity). The clusters significantly differed on several BRIEF sub-scores: shift ($F = 19.3$, $p < 0.001$), emotional control ($F = 6.4$, $p = 0.02$), initiate ($F = 6.3$, $p = 0.03$), organization of materials ($\chi = 14.1$, $p = 0.001$), the composite scores of meta-cognition ($F = 6.7$, $p = 0.02$) and behavioral regulation ($F = 12.4$, $p < 0.001$), as well as the total score of the BRIEF ($F = 12.0$, $p < 0.001$), independently of age, gender and IQ of the individuals. There was a significant difference between clusters 1 and 3, and 2 and 3, for all of these scores except for organization of materials ($t = -0.5$, $p = 1$ between clusters 2 and 3). There was no significant difference between clusters 1 and 2 for all scores, except for organization of materials ($t = -3.3$, $p = 0.004$; Fig. 1C). There was no significant difference between clusters concerning the scores of inhibit ($F = 4.9$, $p = 0.1$), working memory ($F = 3.9$, $p = 0.2$), plan/organize ($F = 4.1$, $p = 0.2$) and monitor ($F = 4.2$, $p = 0.2$).

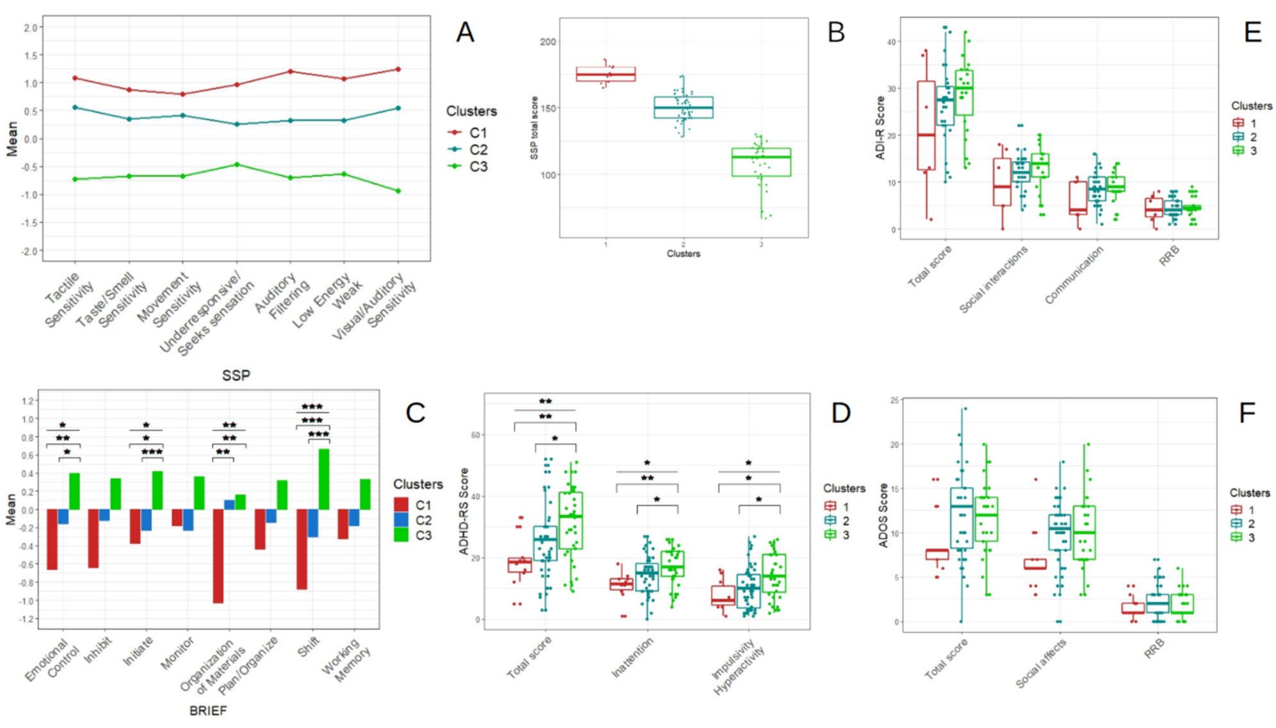

Fig. 1 Latent Profile Analysis (3-clusters solution) on raw scores of the Short Sensory Profile (SSP) questionnaire (**A**). Comparison of the SSP total score (**B**), BRIEF sub-scores (**C**), ADHD-RS total and sub-scores (**D**), ADI-R total and sub-score (**E**) and ADOS-2 total and sub-score (**F**). *RRB* Restricted and Repetitive Behaviors

In our sample, ADHD-RS was available for 93 subjects. There was a significant difference between clusters for the total score (F = 6.2; p = 0.009) as well as the inattention (F = 4.7; p = 0.04) and impulsivity/hyperactivity (F = 5.4; p = 0.02) sub-score, independently of age, gender and IQ of the enrolled individuals. There was a significant difference between clusters 1 and 3, and 2 and 3, for all of these scores (Fig. 1D).

In our sample, the ADI-R was available for 57 subjects, and the ADOS for 88. They did not reveal any significant differences between clusters in the total score or in the ADI-R sub-scores (Fig. 1E), nor for the ADOS-2 total score or sub-scores (Fig. 1F).

Analysis on Normalized Data

The second LPA was run on normalized data and resulted in an optimal solution with two clusters (spherical model with unequal volumes, BIC = − 3741, ICL = − 3765, Log-likelihood = − 1831, df = 17). The clusters included 73 and 22 subjects, respectively. A four-cluster and a three clusters solution were not selected because of the limited number of individuals gathered in one of the clusters (n = 7 and n = 9, respectively). The mean uncertainty was 0.07. This second LPA highlighted two similar sensory profiles, mainly differentiated by the underresponsive/seeks sensations score (Fig. 2A). The two clusters were characterized by the absence of sensory features concerning tactile, movement, taste and smell modalities, and to a lesser extent in visual and auditory sensitivity scores. On the contrary, the 2 clusters are characterized by high symptomatic intensity in the auditory filtering score. Cluster 2, but not cluster 1, was characterized by a high symptomatic intensity in the underresponsive/seeks sensations score. There was a significant difference between the two clusters for the underresponsive/seeks sensations normalized score (F = 9.9, p = 0.02). The total SSP score was significantly different between clusters ($\chi 2 = 23.0$, p < 0.001; Fig. 2B).

We found no significant differences between the two clusters regarding the different scores of the BRIEF (Fig. 2C) and ADHD-RS (Fig. 2D).

The analysis on autism symptomatology found no differences between clusters in total score and subscores of the ADI-R (Fig. 2E) and the ADOS-2 (Fig. 2F).

Discussion

Our study aimed to characterize the executive functions and attentional skills associated with sensory profiles in a heterogeneous population of individuals with IQ-average ASD. Our first LPA, on raw SSP scores, highlighted

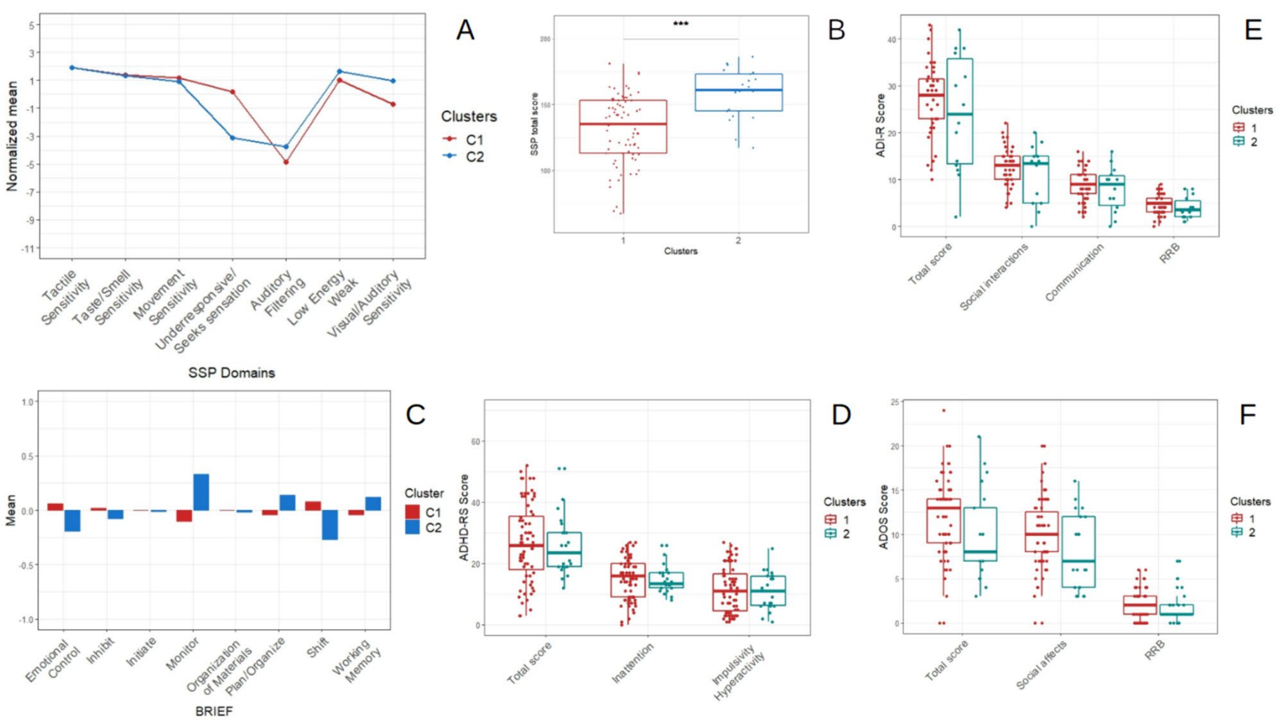

Fig. 2 Latent Profile Analysis (2-clusters solution) on Normalized scores of the Short Sensory Profile (SSP) questionnaire (**A**). Comparison of the SSP total score (**B**), BRIEF sub-scores (**C**), ADHD-RS total and sub-scores (**D**), ADI-R total and sub-score (**E**) and ADOS-2 total and sub-score (**F**). *RRB* Restricted and Repetitive Behaviors

clusters characterized by an increasing global severity of sensory features. There was a statistically significant relationship between executive functions, attentional skills and the overall intensity of sensory features. Our second LPA, on normalized SSP scores, revealed two distinct sensory profiles, mainly differentiated by the score of underresponsive/seeks sensations. We found no statistically significant association between the executive functions or attentional skills and these sensory profiles. Thus, in this study, we found a significant relationship between sensory features and executive functions and attentional skills in ASD. This effect was mainly related to the global intensity of sensory features, rather than to a particular sensory profile.

The LPA on raw data revealed a classification according to the global severity of sensory features, homogeneously between the different SSP scores. Such a severity profile was consistently found in the literature. Indeed, most previous studies identified a group characterized by a low or high symptomatic intensity, across sensory scores in a homogeneous manner (Ausderau et al., 2014a, 2014b; Ben-Sasson et al., 2008; Dwyer et al., 2022; Kaneko et al., 2022; Lane et al., 2012, 2014, 2022; Liss et al., 2006; Simpson et al., 2019; Tillmann et al., 2020). In ASD, such a classification according to symptomatic severity, and not according to qualitative differences, is moreover not specific to sensory features, but is also found in other symptomatic domains (Bitsika et al., 2018), such as Restricted and Repetitive Behaviors (RRB) (Zheng et al., 2019) and global autistic symptomatology (Bitsika et al., 2018).

Our second LPA, on normalized SSP data, allowed us to identify two similar sensory profiles for the vast majority of the SSP scores, with the exception of the underresponsive/seeks sensation score which appeared to be highly discriminating. In our study, cluster 2, characterized by high hyporeactivity and sensation seeking, is similar to the "attenuated-preoccupied" profile found by Ausderau et al., (2014a, 2014b). Our results are similar to a recent study that identified five sensory profiles after LPA using SSP in a population with ASD (Kaneko et al., 2022). Their "variable social/senses" group, characterized by low underresponsive/seeks sensation and auditory filtering scores, correspond to cluster 2. Altogether, these results validate the normalization of SSP scores for our second LPA. Overall, our results are consistent with previous studies showing that sensory hyporeactivity, which characterizes the SSP "underresponsive/seeks sensation" score (Lane et al., 2014), is an important factor in identifying homogeneous subgroups in ASD based on sensory features (Kaneko et al., 2022; Lane et al., 2010, 2014).

This study showed a significant link between executive functions and sensory features as a whole, but not sensory profiles independently of the overall severity. These results appeared consistent with a study conducted on preterm children (Adams et al., 2015). There was a significant correlation between executive function, measured by the BRIEF, and sensory processing, measured by the SSP, in a population of preterm children aged three to five years (Adams et al., 2015). In this study, the BRIEF total score was significantly correlated with all SSP scores, with the exception of Movement Sensitivity. In turn, the BRIEF sub-scores were all correlated with the total SSP score, as were most of its sub-scores. Moreover, our results were in agreement with a recent meta-analysis that found a homogeneous dysfunction on all executive functions in ASD, according to a gradient evolving along the autism spectrum, without difference between the different clinical forms (Demetriou et al., 2018). This study did not reveal any executive profiles in ASD.

Similarly, we found a significant difference in attentional skills between clusters identified by LPA on raw data, but not on normalized data. Thus, attentional difficulties were correlated with sensory features as a whole but were not associated with a particular sensory profile, in accordance with previous studies (Tillmann et al., 2020). The sensory clusters identified in our LPA on normalized data differ mainly by the underresponsive/seeks sensation modality. However, there are currently discrepancies about the relationship between sensory seeking behaviors and attentional difficulties. Some studies showed a weak correlation between sensory seeking behaviors or sensory underresponsiveness and overfocused attention, which was more likely to be correlated with sensory hypersensitivity (Liss et al., 2006). However, other studies showed that the seeking behavior dimension was strongly correlated with attentional difficulties (Alateyat et al., 2022; Dellapiazza et al., 2021; Sabatos-DeVito et al., 2016). Our results are consistent with the study by Little et al., (2017) which found no difference neither in sensory processing pattern nor in particular seeking score, nor attention skills, between ASD and ADHD groups (Little et al., 2017). Our study supports the hypothesis that attentional difficulties and sensory profiles, mainly discriminated by underresponsive/seeks sensation score, are independent.

It remains unclear whether sensory features in ASD are a consequence of impairments in bottom-up or top-down cognitive processing (Uljarević et al., 2017). Some studies suggested that early sensory deficits in individuals with autism may underlie executive dysfunction (Robertson & Baron-Cohen, 2017). As sensory perception occupies a central place in children's psychomotor and cognitive development, a disruption of sensory perceptual processes would have significant repercussions on executive functions (Baranek et al., 2018). On the contrary, the predominant perception of details in ASD (Happé et al., 2006) could be linked to an abnormal attentional focus (Thielen & Gillebert, 2019) associated with a defect in cognitive flexibility, which could lead to sensory impairment (Allen, 2001). Our study supports the hypothesis of a strong link between executive function, attentional skills and sensory perception as a whole, but our results are correlational in nature and does not allow us to determine the direction of a causal link. Longitudinal studies could be helpful in bridging this gap.

Our study has several limitations and advantages. The BRIEF and the SSP represent the most widely used hetero-questionnaires in ASD for the assessment of executive function and sensory features, respectively (Demetriou et al., 2019; Dunn et al., 2016). They were designed to maximize ecological validity. However, some authors have suggested that the BRIEF instead measure executive dysfunction as a whole (Geurts et al., 2009), which may partially explain our results. The 7 scores of the SSP were identified through a factor analysis performed in a population of neurotypical children (McIntosh et al., 1999). A replication of this factor analysis in a population with ASD resulted in a slightly different partitioning (Tomchek et al., 2014). Although the SSP is one of the most widely used and consensual tools for measuring sensory impairment in ASD (Ben-Sasson et al., 2019), some authors advocate for the use of modified versions to more finely tune to autistic features (Williams et al., 2018). In addition, because the BRIEF and SSP are parent questionnaires, the measurement of executive function and sensory features relies on observation of relatives, which may carry significant biases. However, the link between executive function and sensory features does not seem to be impacted by a parent report bias in preterm population (Adams et al., 2015). In addition, while the SSP is calibrated for a population aged 3 to 14 years and 11 months (McIntosh et al., 1999), the age range of our sample is 6 to 17 years. However, the sample aged 14 years and 11 months to 17 years represents only 6.3% of our total population (6 subjects). Therefore, it is unlikely to significantly influence our results. Finally, our study is cross-sectional and does not allow us to estimate the evolution of identified clusters over time. Longitudinal studies are needed to assess the stability and generalizability of these subgroups over time and across different populations.

Our study challenges recent findings suggesting that sensory features allow for the formation of clinically relevant subgroups to reduce the heterogeneity of ASD (Uljarević et al., 2017). We found a significant association between sensory features and executive functions, which could have an impact on the care of patients with ASD. Thus, it seems relevant to take into account executive dysfunction in individuals with significant sensory features. Similarly, our study highlighted the relevance of considering attentional difficulties in these individuals. More powerful studies are needed to clarify the differences in attentional abilities between distinct sensory profiles and to determine the direction of a causal link between these conditions.

Author contributions HP, RD and PA contributed to the study conception and design. Data collection was performed by AM, EH, PE, AC, AL, RD and HP. Statistical analysis was performed by PA. The first draft of the manuscript was written by PA and HP and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability Full access to code and data.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Informed Consent All participating families signed an informed consent form.

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