META-ANALYSIS

Sensory Processing in Individuals With Attention-Deficit/Hyperactivity Disorder Compared With Control Populations: A Systematic Review and Meta-analysis

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Objective: To evaluate the association between attention-deficit/hyperactivity disorder (ADHD) and atypical sensory processing patterns.

Method: For this systematic review and meta-analysis, PubMed, Embase, and Web of Science were searched from their inception until June 30, 2024. Studies examining sensory processing patterns using questionnaires in participants with a diagnosis of ADHD compared with healthy controls were included. The study risk of bias was assessed using a modified Newcastle-Ottawa Scale. A random-effects meta-analysis was conducted using R Version 4.3.1 software, considering sensory modulation severity atypicities as the primary outcome. The risk of publication bias was explored, and sensitivity analyses were conducted to test the robustness of findings.

Results: After screening 10,750 references, 30 studies (reported in 32 publications) encompassing 5,374 participants were included, with 23 studies focusing on children and 7 focusing on adults. Patients with ADHD presented with significantly more severe sensory atypicities than the control group in multiple domains: sensory sensitivity (k = 13, SMD = 1.17, 5% CI [0.75, 1.59], I^2 = 87%), sensory avoiding (k = 11, SMD = 1.15, 95% CI [0.66, 1.64], I^2 = 92%), low sensory registration (k = 23, SMD = 1.22, 95% CI [0.89, 1.56], I^2 = 92%), and sensory seeking (k = 15, SMD = 1.23, 95% CI [0.48, 1.97], I^2 = 97%). Heterogeneity was high in all analyses. Only 9 studies were deemed at overall low risk of bias.

Conclusion: Even though available ADHD clinical guidelines do not specifically mention the need to assess sensory processing in ADHD, this meta-analysis suggests that this should be systematically explored in the evaluation of children and adults referred for ADHD.

Study registration information: Association between ADHD and sensory processing disorder: A systematic review and meta-analysis; https://www.crd.york.ac.uk/PROSPERO/view/CRD42022325271.

Diversity & Inclusion Statement: We actively worked to promote sex and gender balance in our author group. One or more of the authors of this paper self-identifies as a member of one or more historically underrepresented sexual and/or gender groups in science. One or more of the authors of this paper self-identifies as a member of one or more historically underrepresented racial and/or ethnic groups in science.

Key words: attention-deficit/hyperactivity disorder; meta-analysis; sensory modalities; sensory processing; systematic review

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Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity-impulsivity, or both that interfere with daily functioning and development.[1] It is the most prevalent neurodevelopmental condition, is more common in males, and is estimated to affect about 5% of youth[2] and 3% of adults.[3] ADHD is frequently associated with other physical and psychiatric disorders, such as neurodevelopmental, conduct, anxiety, and mood disorders.[4,5]

Theorized initially in the 1970s by Ayres,[6] sensory integration is the process by which one registers, modulates, and discriminates sensations received through sensory systems (visual, auditory, gustatory, olfactory, tactile, proprioceptive, and vestibular) to produce purposeful, adaptive behaviors in response to the environment. Atypical sensory processing patterns (SPPs) can impact the development of behavioral, emotional, motor, and cognitive domains.[7,8] Dunn's model[9] describes sensory modulation as the interaction between the neurological threshold and self-regulation. A low neurological threshold means that a person's neurons are activated and cause a response even to low-intensity stimuli. Conversely, a high neurological threshold indicates that triggering the same neurological response requires more intense stimuli. According to Dunn, sensory modulation can be classified into four domains (or quadrants): sensitivity (low threshold and passive self-regulation strategy); avoiding (low threshold and active self-regulation strategy); seeking (high threshold and active self-regulation strategy); and registration (high threshold and passive self-regulation strategy).

The estimated prevalence of atypical SPPs ranges from 5% to 16% in neurotypical people[10,11] and from 30% to 80% in people with developmental disabilities.[12-14] Atypical SPPs may affect cognitive functions and psychosocial development,[9] impact the intensity and enjoyment of engaging in social relationships,[15] and increase emotional and attentional regulation difficulties.[16]

In *DSM-5-TR*, atypical SPPs are not included as a specific diagnosis category.[1] However, sensory processing disorder has been included in some diagnostic classifications for developmental disorders in early childhood (eg, Developmental Disorders of Infancy and Early Childhood [DC: 0-5][17]) and is now listed among the possible symptoms of autism spectrum disorders in *DSM-5-TR*.[1]

Previous studies showed that individuals with ADHD may also be at a higher risk of having atypical SPPs.[18,19] However, the exact extent to which SPPs are atypical in, namely, ADHD is unclear, and indeed current clinical guidelines for ADHD do not include the assessment of SPPs.

Thus, investigating SPPs in ADHD has high clinical relevance, as it may inform future clinical guidelines and recommendations. This systematic review and meta-analysis aimed to quantitatively synthesize studies comparing SPPs in participants with ADHD and controls from the general population.

METHOD

This study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[20] (see Supplement 1, available online, for the checklists). This review was registered in PROSPERO in May 2022 (CRD42022325271).

Literature Search

The electronic databases Medline, Embase, and Web of Science were searched from inception until June 30, 2024. The search strategy was designed by an information specialist and specialists in the field and included terms related to ADHD and SPPs. The terms were combined with MEDLINE filters to exclude nonrelevant review articles. The search terms were adapted for use with other bibliographic databases in combination with database-specific filters where these are available. From the last search until September 1, 2024, monitoring of the 3 databases was performed, but no new study was included. We used a combination of free text and thesaurus terms for concepts relevant to the topic. The search algorithms are described in Supplement 1, available online. The reference lists of reviews related to our subject were also screened.[14,21-24]

Study Selection

The inclusion and exclusion criteria were as follows:

1. We included studies in which ADHD was diagnosed by a clinician with or without use of tools based on established diagnostic criteria (including *DSM-III* and later editions and *ICD-9* and later revisions). Studies including participants with ADHD symptoms only without a formal clinical diagnosis were excluded.
2. Studies including participants with more than 20% of comorbid autism spectrum disorder, intellectual disability, or genetic disorders were not included.
3. Studies included a control group without ADHD. A clinical control group (homogeneous diagnosis in the control group) was not accepted.
4. Original cohort, case-control, and cross-sectional studies were included. Case reports were excluded.

Outcomes were the severity of SPP atypicities and the risk of being hyposensitive or hypersensitive. Assessment of each outcome could occur before or after the diagnosis of ADHD using questionnaires (self-reports, parent reports, teacher reports or semistructured interviews). Sensory-based motor disorders (dyspraxia and postural disorder) were not evaluated in this systematic review.

Screening and Data Extraction

Two independent reviewers (A.D. or Ch.G. and L.J.) conducted the literature search. Duplicate reports of the same studies were removed. Duplicates were managed using Zotero for the first search and Covidence for the update. Two reviewers (A.D. or Ch.G. and L.J.) checked eligibility of the studies from titles and abstracts first, followed by full-text reading.

The following variables were extracted by 2 independent reviewers (A.D. or Ch.G. and L.J.) using a standardized extraction form: study design; sample size and description (eg, clinical-based, population-based);

comparison group description (eg, matching criteria, sibling controls, healthy volunteers); ADHD and SPP assessment methods; population characteristics (eg age, gender, race/ethnicity, IQ, medication, comorbidities); and outcome results, including means, SDs, and prevalence in each group.

In case of discrepancies between the 2 reviewers during the selection or the data extraction process, a third author (M.N.) was consulted. In case of missing information to assess the eligibility criteria or to complete data extraction, the study's corresponding author was contacted.

Risk-of-Bias Assessment

Two reviewers (A.D. or Ch.G. and L.J.) independently assessed the quality of each study by using a modified Newcastle Ottawa Scale (NOS). The NOS contains 7 items categorized into 3 dimensions: selection, comparability, and outcome. The maximum total score was 10 points. To better reflect efforts to ensure comparability across study populations, we assigned an additional point for representative samples. The evaluation of the NOS outcome dimension was modified to allow a maximum of 1 point, as only unblinded studies were included (see Supplement 1, available online, for more details on the NOS). As in previous studies, we considered a study that scored ≥ 7 to have a low risk of bias. Studies scoring between 4 and 7 points were at an unclear risk of bias, whereas studies scoring less than 4 points were at a high risk of bias.[25]

Data Analysis

Outcomes. Outcomes were the severity of SPP atypicities and the risk of being hyposensitive or hypersensitive. The severity of SPP atypicities was divided as follows: the sensory modulation disorder according to each Dunn quadrant (sensory sensitivity, low sensory registration, sensory seeking, and sensory avoiding), using continuous measures, and the sensory discrimination disorder according to each sensory modality (tactile, auditory, visual, oral [taste/smell], movement [vestibular], and body position [proprioception]), using continuous measures.

The assessment tools for each continuous outcome are outlined in Supplement 1, available online. In one study[26] using the Sensory Over-Responsivity scale, the taste and smell domains were combined as "oral sensory." To calculate the SD, a correlation of 0.41 between the 2domains was used.[27] For the risk of being hyposensitive or hypersensitive (binary outcome), the number of participants classified as hypersensitive ("more than others" or "much more than others" on sensory sensitivity) and hyposensitive ("less than others" or "very much less than others" on low registration) in both groups were retrieved. Primary outcomes were sensory modulation disorder severity according to each Dunn quadrant.

Statistical Analyses. For continuous outcomes, effect size estimates were based on standardized mean differences (SMDs) between the ADHD and control groups using Hedges g small sample bias adjustment.[28] For binary outcomes, pooled odds ratios (ORs) were estimated using the number of hypersensitive or hyposensitive diagnoses in participants with ADHD and controls. We conducted a random-effects meta-analysis for all outcomes. The Hartung-Knapp adjustment was used to estimate CI.[29] Pooled SMDs and ORs were estimated using the inverse variance method. Heterogeneity was quantified using τ^2 (estimated using restricted maximum likelihood) and I^2 statistics.

Prespecified subgroup analyses were conducted for all outcomes, with subgroups defined by study population (children or adults) and risk of bias (low, unclear, or high). We also conducted 3 post hoc subgroup analyses. The first analysis was based on the type of SPP assessment tool used; the second analysis separated studies in which ASD was clearly excluded from studies where the exclusion of ASD was unclear (eg, not reported, self-reported diagnosis, or use of a screening tool); and the third analysis separated studies into those that excluded participants with low IQ, studies that did not exclude participants with low IQ, and studies where information on possible exclusion based on IQ was not available.

We ran prespecified meta-regressions with the following variables: mean age, proportion of female participants, and proportion of ADHD participants taking medication. A post hoc meta-regression with publication year was performed. Publication bias was visually assessed using a funnel plot and the Egger regression test for asymmetry. In case of asymmetry, a trim-and-fill method was used to adjust for publication bias in the meta-analysis.[30] Regression-based tests were conducted if at least 10 studies were available per predictor. All analyses were conducted using the meta package version 7.0-0[31] in R version 4.3.1.[32]

Deviation From Protocol. We were unable to conduct a sensitivity analysis on subtypes of ADHD or age at diagnosis of ADHD, as this information was rarely reported. The impact of the study design and different control groups was not assessed, as study designs and control groups tended to be the same across studies.

RESULTS

Study Selection

The literature search generated 10,750 references. After removal of duplicates, 6,526 records were screened based on the title and abstract, of which 84 were assessed for eligibility by full-text review. Of these 84 articles, 52 were excluded. A total of 30 studies (32 reports) were included in the quantitative synthesis. The PRISMA flowchart and the reasons for exclusions are presented in Supplement 1, available online. Of the 15 authors who were contacted to retrieve missing information from their study, only 1 author responded.

Study Characteristics

The characteristics of the included studies are presented in Table 1.[18,19,26,33-59] The total population included 5,374 participants (ADHD participants = 1,656 and controls = 3,718). Studies were published between 2001 and 2024. They were conducted in North America (k = 8), Europe (k = 7), Middle East (k = 6), Asia (k = 8), and South America (k = 1). All were cross-sectional studies.

Female participants were less represented than male participants, with a mean of 30% female participants (range 0%-67%). The mean age ranged from 4.7 to 34 years in the ADHD group and 4.8 to 32.1 in the control group. Of studies, 23 focused on children, 6 focused on adults, and 1 focused on adolescents and young adults (>16 years old).

Ethnicity of all participants was reported in 4 studies, 1 study provided information on ethnicity only for the control group, and 25 studies did not report ethnicity at all. Among the studies reporting ethnicity, the majority of the population was White (the term Caucasian is used Table 1 as it appears in the original studies included in this review).

Concerning IQ, 20 studies excluded participants with low IQ, 2 did not exclude participants with low IQ, and 9 did not provide any information on this criterion. The mean IQ in the ADHD group ranged from 72.06 to 119.4, whereas mean IQ in the control group ranged from 94.3 to 119.9.

The ADHD diagnosis was assessed using diagnostic criteria (*DSM-IV*, *DSM-IV-TR*, *DSM-5*, or *ICD-10*) in 18 studies or by a clinician without indicating the precise tool used. Other studies used chart reviews or mixed methods to assess diagnosis.

For participants with ADHD, medication was an exclusion criterion in 2 studies. Nine studies included participants with medication (see Supplement 1, available online, for details), and 19 studies did not provide any information on medication.

Comorbidities (excluding ASD) were described in 9 studies. Oppositional defiant disorder was the most frequent comorbidity. Comorbidities were excluded from 7 studies, and 14 studies did not provide any information. Concerning ASD, 20 studies excluded participants with ASD, 1 study included 4 participants with ADHD and ASD, and 9 studies did not provide any information regarding ASD.

The included studies used the following questionnaires to assess SPP: the Sensory Profile (SP) (k = 8, of which 2 studies used an adapted Chinese version [C-SP]), the Short Sensory Profile (SSP) (k = 6), the Adolescent/Adult Sensory profile (AASP) (k = 7), the Sensory Profile-2 (SP-2) (k = 3), the Sensory Over-Responsivity (SOR) scale (k = 1), the Sensory Processing 3-Dimensions Scale (SP-3DS) (k = 1), the Sensory Processing Measure (k = 2), the Touch Inventory for Elementary-School-Aged Children (TIE) (k = 1). One study used a newly designed and validated tool, the Sensory Perception Questionnaire (SPQ).

Risk of Bias

The overall quality of each study is reported in Supplement 1, available online. Nine studies were considered to have a low risk of bias, 19 studies were considered to have an unclear risk of bias, and 2 studies were considered to have a high risk of bias.

Major issues were found in the population selection. Only 3 studies estimated an a priori sample size, and only 2 studies described nonrespondents. The sampling strategy was rarely based on randomization or selection of all eligible participants. In most studies, the ADHD and control groups were sampled from different populations (outpatients for the ADHD group and volunteers from the general population for the control group, sometimes from the same region/schools).

Meta-analyses: Sensory Quadrants

This section presents the main results. All sensitivity analyses (subgroups, meta-regressions, leave-one-out analysis) and publication bias analyses plots are presented in Figures S1 to S33, available online.

Sensory Sensitivity. The meta-analysis on sensory sensitivity included 13 studies (ADHD participants = 626, controls = 991). Sensory sensitivity was higher in the ADHD group compared with the control group (SMD = 1.17, 95% CI [0.75,1.59]), observed in both adults and children (Figure 1). Heterogeneity was high ($I^2 = 87\%$). A meta-regression on the year of the study revealed a significant effect with a larger SMD in most recent studies (estimate = 0.096, 95% CI [0.047, 0.144]), reducing the heterogeneity to 68.65%. Subgroup analyses indicated a significant difference based on the risk of bias ($p < .01$). When focusing only on studies with a low risk of bias, the difference between groups was no longer significant, with large CI explained by the insufficient number of studies

TABLE 1 Characteristics of Populations in Included Studies

Authors, year, reference	Country	Setting	N	% Female	Age, y, mean (SD))	Race/ethnicity	IQ, mean (SD)	Type of ADHD diagnosis	Comorbidity	ADHD medication	Sensory assessment
Mangeot *et al.*, 2001[33]	USA	Control: volunteers	30	30	8.2 (2)	NR	108.91 (10.68)	Clinical diagnosis (CAP)	NR	Total = 15; 8 MPH, 2 clonidine, 5 others	SSP
		ADHD: outpatients	26	31	8.3 (2.4)		72.06 (9.69)				
Dunn and Bennett, 2002[19]	USA	Control: randomly selected matched controls	70	13	8.6	NR, discussed by authors as a limitation	NR	*DSM-IV*	ADHD: 23 ODD, 1 posttraumatic stress disorder, 1 adjustment disorder, 10 learning disorders, 2 encopresis ASD excluded	Total = 52	SP
		ADHD: outpatients	70	13	8.6						
Yochman *et al.*, 2004[18]	Israel	Control: matched controls, cohort	46	20	4.8 (0.62)	NR	Low IQ excluded	Clinical diagnosis (pediatrician)	ASD excluded	NR	SP
		ADHD: cohort (same as control)	48	19	4.7 (0.76)						
Bröring *et al.*, 2008[34] (males)	Europe	Control: volunteers from same region	16	0	9.7 (0.6)	All children were European Caucasian[a] descent	Low IQ excluded	*DSM-IV-TR*	ASD excluded	Total = 28; 25 psychostimulant, 1 nonstimulant, 2 combination	TIE
		ADHD: outpatients	35	0	10 (1.7)						
Bröring *et al.*, 2008[34] (females)	Europe	Control: volunteers from same region	19	100	9.4 (0.8)	All children were European Caucasian[a] descent	Low IQ excluded	*DSM-IV-TR*	ASD excluded	Total = 8; 6 psychostimulant, 2 nonstimulant	TIE
		ADHD: outpatients	12	100	10 (1.1)						
Cheung and Siu, 2009[35]	China	Control: randomly selected from schools	1,840	50.3	7.25 (2.8)	NR	NR	*DSM-IV-TR*	ASD excluded	NR	C-SP
		ADHD: inpatients	114	NA	7.9 (1.4)						
Miller *et al.*, 2012[36]	USA	Control: volunteers	57	49	8.09 (2.68)	African American (3%), Asian (3%), Caucasian[a] (89%), Hispanic (2%), Native American (1%), other (2%)	100.95 (11.3)	Clinical diagnosis	Excluded (ASD excluded as well)	Total = 17 9 MPH, 4 dextroamphetamine, 1 fluoxetine, 3 combination	SSP
		ADHD: outpatients	37	24	9.99 (2.26)		73.92 (8.65)				

(*continued*)

TABLE 1 Continued

Authors, year, reference	Country	Setting	N	% Female	Age, y, mean (SD))	Race/ethnicity	IQ, mean (SD)	Type of ADHD diagnosis	Comorbidity	ADHD medication	Sensory assessment
						ethnicities No differences between groups with respect to ethnicity ($p > .05$)					
Lin *et al.*, 2013[37]	Taiwan	Control: matched children from local schools	20	0	9.1 (1.79)	NR	Low IQ excluded	*DSM-IV-TR*	NR	NR	C-SP
		ADHD: outpatients	20	0	8.64 (2.57)						
Lufi and Tzischinsky, 2014[38]	Israel	Control: volunteers from local schools	28	50	15.64 (1.5)	NR	NR	Clinical diagnosis (CAP)	NR	Total = 27 MPH only	AASP
		ADHD: outpatients	30	10	15.1 (1.27)						
Shimizu *et al.*, 2014[39]	Brazil	Control: volunteers from same school	37	19	8.9 (1.49)	NR	Low IQ excluded	*DSM-IV-TR*	13 affective disorder, 13 anxiety disorder, 21 ODD, 22 CD ASD excluded	NR	SP
		ADHD: outpatients	37	19	8.9 (1.49)						
Pfeiffer *et al.*, 2015[40]	USA	Control: mixed (outpatients, volunteers, etc)	27	52	8.3 (1.6)	African American (12.8%), Asian (12.8%), Caucasian[a] (61.7%), Hispanic (6.4%), Native American (2.1%), other (4.3%) ethnicities The group without ADHD included more Asian American children ($\chi^2 = 12.34$, $p < .05$)	Low IQ excluded	Mixed (clinician, *DSM-IV-TR*)	3 ADHD and comorbid diagnosis ASD excluded	Total = 12	SPM
		ADHD: outpatients	20	25	9.1 (1.3)						
Bijlenga *et al.*, 2017[41]	Netherlands	Control: norm group from AASP	496	51	NA	92% Caucasian in norm group; no information for ADHD group	NR	DIVA-5	42 sleep disorders, 22 depression, 17 anxiety disorder, 20 drug dependence, 4 autism, 11 impaired hearing, 1 visual disability, 5 olfactory and/or gustatory disabilities, 3 tactile disabilities	Total = 48; 30 ADHD medication and 18 antidepressant	AASP
		ADHD: outpatients	116	38	32 (10.2)						

(*continued*)

TABLE 1 Continued

Authors, year, reference	Country	Setting	N	% Female	Age, y, mean (SD))	Race/ethnicity	IQ, mean (SD)	Type of ADHD diagnosis	Comorbidity	ADHD medication	Sensory assessment
Sanz-Cervera *et al.*, 2017[42]	Spain	Control: volunteers from local schools	27	30	6.28 (1.11)	NR	98.04 (17.21)	*DSM-IV-TR*	Excluded (ASD excluded as well)	NR	SPM
		ADHD: outpatients	21	14	6.81 (1.1)		87.43 (14.38)				
Little *et al.*, 2018[43]	USA	Control: matched controls (cohort)	84	25	8.77	Asian (3.1%), Black (16%), Hispanic (20.4%), White (51.2%), other (9.3%) ethnicity	NR	Chart review	ASD excluded	NR	SP-2
		ADHD: cohort (volunteers), same cohort as control	78	22	9.7						
Mimouni-Bloch, 2018[44,b]	Israel	Control: volunteers	39	59	9.46 (0.9)	NR	Low IQ excluded	*DSM-5*	Excluded (ASD excluded as well)	NR	SSP
		ADHD: outpatients	38	29	9.31 (0.85)						
Jegadeesan *et al.*, 2020[45]	India	Control: volunteers from local schools	50	NA	NA	NR	Low IQ excluded	Clinical diagnosis (pediatrician)	NR	NR	SSP
		ADHD: outpatients	50	NA	NA						
Kamath *et al.*, 2020[46]	USA	Control: cohort	22	55	21.14 (2.25)	NR	111.18 (10.14)	*DSM-5*	Excluded (except depression and anxiety)	NR	AASP
		ADHD: cohort (same as control)	23	61	21.87 (1.98)		109.1 (8.75)				
Ohta *et al.*, 2020[47]	Japan	Control: volunteers	58	16	29.4 (6.7)	NR	107.7 (7.7)	*DSM-IV-TR*	Excluded (ASD excluded as well)	Total = 32 30 ADHD medication and 2 antipsychotics	AASP
		ADHD: outpatients	55	24	31.2 (8.8)		106.3 (12.5)				
Adra *et al.*, 2021[48]	USA	Control: volunteers from general population	29	69	27 (5.8)	NR	119.9 (13.9)	*DSM-5*	None reported, ASD excluded	NR	SP-3DS
		ADHD: volunteers from general population	25	56	26.4 (6.7)		119.4 (13.5)				
Dellapiazza *et al.*, 2021[49]	France	Control: matched children from local schools	31	39	9.3 (1.6)	NR	NR	*DSM-5*	ASD excluded	No medication	SP
		ADHD: outpatients	28	18	9.2 (1.8)		109 (16.2)				
Gomez *et al.*, 2021[50]	Philippines	Control: volunteers from local schools	42	0	8.9 (1.52)	NR	Low IQ excluded	Clinical diagnosis (therapy center)	None reported, ASD excluded	NR	SP
		ADHD: outpatients	24	0	9.4 (1.71)						
Grinblat and Rosenblum, 2022[51,b]	Israel	Control: matched volunteers	52	69	32.1 (6.56)	NR	Low IQ excluded	Clinical diagnosis	75% of ADHD group had at least 1 psychiatric comorbidity	NR	AASP
		ADHD: volunteers	69	65	33.42 (6.39)						
Sobhy *et al.*, 2022[52]	Egypt	Control: volunteers from nursery and schools	40	65	4.53 (0.98)	NR	NR	*DSM-5*	ASD excluded	NR	SPQ
		ADHD: outpatients	30	27	4.51 (0.96)						
Darnal *et al.*, 2023[53]	India	Control: volunteers from local schools	139	NA	6-18	NR	Low IQ excluded	*ICD-10*	Excluded (ASD excluded as well)	NR	SSP
		ADHD: NR	100	NA							
Panda *et al.*, 2023[54]	India	Control: matched controls	33	9	10.8 (1.6)	NR	94.3 (2.1)	*DSM-5*	More than 50% of ADHD group had	Total = 63; 34 atomoxetine, 22	SP-2

(*continued*)

TABLE 1 Continued

Authors, year, reference	Country	Setting	N	% Female	Age, y, mean (SD))	Race/ethnicity	IQ, mean (SD)	Type of ADHD diagnosis	Comorbidity	ADHD medication	Sensory assessment
		ADHD: outpatients	66	9	10.7 (1.9)		90.1 (3.5)		a learning disorder or ODD; 30% had sleep problems; some reported CD, anxiety, or depression ASD excluded	MPH, 2 clonidine, 5 atomoxetine+MPH	
Rani *et al.*, 2023[55]	India	Control: matched controls	34	6	8.35 (2.47)	NR	94.8 (5.8)	*DSM-5*	31.6% had a psychiatric comorbidity (ODD, anxiety, or CD) ASD excluded	NR	SP-2
		ADHD: outpatients	38	5	8.45 (2.27)		92.1 (6.4)				
Schramm *et al.*, 2023[56]	Germany	Control: matched controls	14	36	32.14 (9.93)	NR	Low IQ excluded	Clinical diagnosis	Excluded	Total = 10; 9 MPH and 1 bupropion	AASP
		ADHD: outpatients	15	33	34 (7.1)						
Schulz *et al.*, 2023[57]	Canada	Control: cohort	163	44	11.29 (3.46)	NR	109.56 (12.14)	Clinical diagnosis	NR	NR	SSP
		ADHD: cohort (same as control)	317	27	10.82 (3.43)		93.15 (14.87)				
Fabio *et al.*, 2024[58]	Italy	Control: matched children, cohort	69	35	16.2 (1.9)	NR	NR	*DSM-5*	Excluded	NR	AASP
		ADHD: cohort (same as controls)	69	35	Age from global cohort						
Martínez-González *et al.*, 2024[26]	Spain	Control: volunteers randomly selected	76	62	19.18 (4.44)	NR	Low IQ excluded	Clinical diagnosis	Excluded (ASD excluded as well)	NR	SOR
		ADHD: outpatients	15	53	18.87 (2.41)						
Mohammed *et al.*, 2024[59]	Egypt	Control: control from nursery and schools	30	27	6.04 (2.29)	NR	NR	*DSM-5*	NR	No medication	SP
		ADHD: outpatients	30	27	6.03 (2.17)						

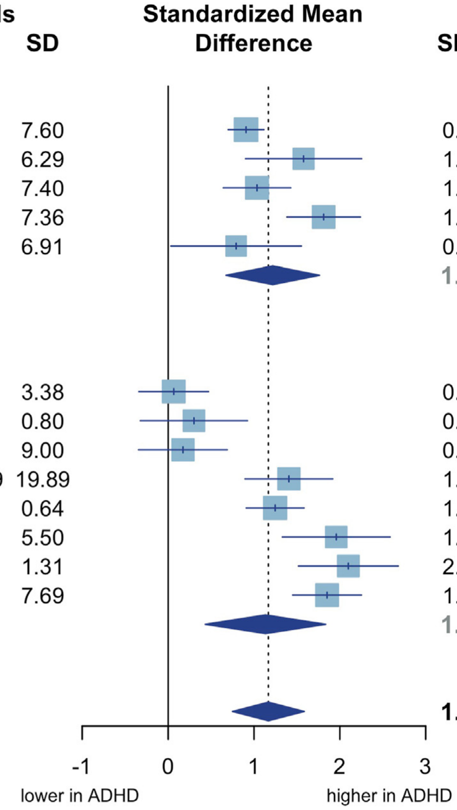
Note: ADHD = attention-deficit/hyperactivity disorder; AASP = Adolescent/Adult Sensory Profile; ASD = autism spectrum disorder; CAP = child and adolescent psychiatrist; CD = conduct disorder; C-SP = Chinese Version Sensory Profile; DIVA-5 = Diagnostic Interview for ADHD in Adults; MPH = methylphenidate; NA = not available; NR = not reported; ODD = oppositional defiant disorder; SOR = Sensory Over-Responsivity (scale); SP = Sensory Profile; SP-2 = Sensory Profile-2; SP-3DS = Sensory Processing 3-Dimensions Scale; SPM = Sensory Processing Measure; SPQ = Sensory Perception Questionnaire; SSP = Short Sensory Profile; TIE = Touch Inventory for Elementary-School-Aged Children.

[a]The term Caucasian is used here as it appears in the original studies included in this review.

[b]The Grinblat and Rosenblum study from 2022[51] and the Mimouni-Bloch study from 2018[44] were kept for the analyses, but results are also reported in Grinblat and Rosenblum from 2021[60] and Mimouni-Bloch et al. in 2017.[61]

FIGURE 1 Forest Plot of Meta-analysis on Sensory Sensitivity

Study	ADHD Total	ADHD Mean	ADHD SD	Controls Total	Controls Mean	Controls SD	SMD	95%-CI	Weight
adults									
Bijlenga et al. 2017 [43]	116	40.90	9.20	496	33.70	7.60	0.91	[0.70; 1.12]	8.7%
Kamath et al. 2020 [48]	23	43.04	8.74	22	30.77	6.29	1.58	[0.90; 2.25]	6.9%
Ohta et al. 2020 [49]	55	41.80	9.60	58	32.90	7.40	1.03	[0.64; 1.43]	8.2%
Grinblat et al. 2022 [53]	69	46.54	9.74	52	30.50	7.36	1.81	[1.38; 2.24]	8.0%
Schramm et al. 2023 [58]	15	42.60	9.22	14	35.93	6.91	0.79	[0.03; 1.55]	6.5%
Random effects model	**278**			**642**			**1.22**	**[0.67; 1.76]**	**38.4%**
Heterogeneity: I^2 = 76%, τ^2 = 0.1378, p < 0.01									
children									
Yochman et al. 2004 [35]	48	-16.06	4.19	46	-16.31	3.38	0.06	[-0.34; 0.47]	8.1%
Lin and al. 2013 [39]	20	-0.19	0.83	20	-0.44	0.80	0.30	[-0.32; 0.92]	7.2%
Lufi and al. 2014 [40]	30	22.17	6.70	28	20.79	9.00	0.17	[-0.34; 0.69]	7.7%
Shimizu et al. 2014 [41]	37	-130.92	21.68	37	-160.49	19.89	1.41	[0.89; 1.92]	7.7%
Little and al. 2018 [45]	78	2.44	0.81	84	1.53	0.64	1.25	[0.91; 1.58]	8.4%
Dellapiazza et al. 2021 [51]	28	-78.20	9.50	31	-93.40	5.50	1.96	[1.33; 2.59]	7.2%
Rani et al. 2023 [57]	38	38.47	11.20	34	21.09	1.31	2.10	[1.52; 2.68]	7.4%
Fabio et al. 2024 [60]	69	48.39	9.91	69	31.88	7.69	1.85	[1.45; 2.25]	8.1%
Random effects model	**348**			**349**			**1.13**	**[0.43; 1.84]**	**61.6%**
Heterogeneity: I^2 = 91%, τ^2 = 0.6345, p < 0.01									
Random effects model	**626**			**991**			**1.17**	**[0.75; 1.59]**	**100.0%**
Heterogeneity: I^2 = 87%, τ^2 = 0.4086, p < 0.01									
Test for subgroup differences: χ^2_1 = 0.06, df = 1 (p = 0.81)									



Note: *ADHD = attention-deficit disorder with or without hyperactivity; SMD = standardized mean difference. Please note color figures are available online.*

(n = 4) and the high heterogeneity. No outliers were detected in the leave-one-out sensitivity analysis, and no publication bias was found on funnel plot visual inspection or the Egger test.

Sensory Avoiding. The meta-analysis on sensory avoiding included 11 studies (ADHD participants = 558, controls = 925). Sensory avoiding was higher in the ADHD group compared with the control group (SMD = 1.15, 95% CI [0.66, 1.64]) in adults as well as children (Figure 2). Heterogeneity was high (I^2 = 92%). Subgroup analyses indicated a significant difference based on the risk of bias (p < .01). When focusing only on studies with a low risk of bias, the difference between groups was no longer significant with large CI explained by the insufficient number of studies (n = 3) and the high heterogeneity.

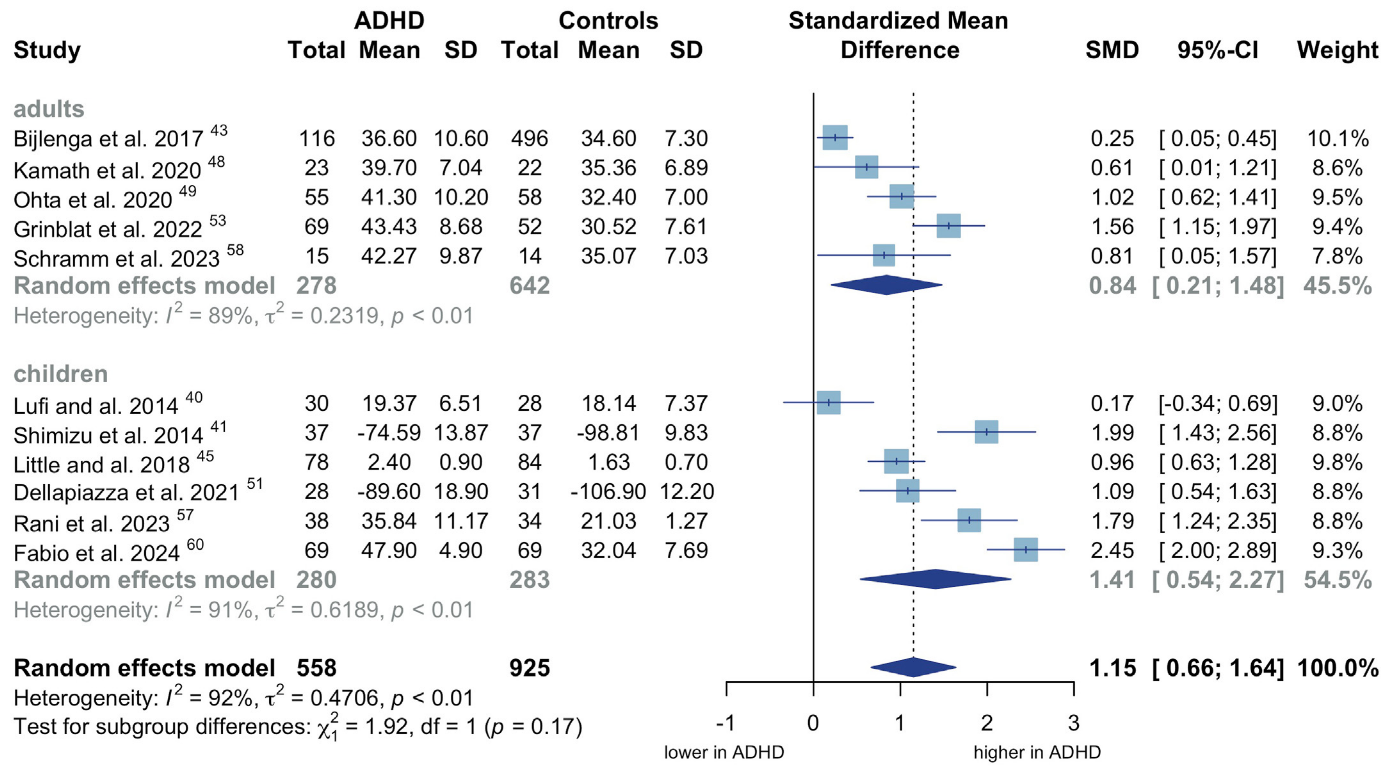
No outliers were detected in leave-one-out sensitivity analysis. Publication bias was found on funnel plot visual inspection. The adjusted result with trim-and-fill procedure showed no difference between the groups (SMD = 0.57, 95% CI [−0.03, 1.16]).

Low Sensory Registration. The meta-analysis on low sensory registration included 23 studies (ADHD participants = 1,374, controls = 1,677). Low sensory registration was higher in the ADHD group compared with the control group (SMD = 1.22, 95% CI [0.89, 1.56]), in both adults and children (Figure 3). Heterogeneity was high (I^2 = 92%). Meta-regression on age revealed a significant effect (estimate = 0.04, 95% CI [0.003, 0.076]) with higher SMD with higher age. Accounting for age reduced the heterogeneity to 88.52%.

No outliers were detected in leave-one-out sensitivity analysis. Publication bias was found on funnel plot visual inspection and the Egger test. The adjusted result with the trim-and-fill procedure remained higher in the ADHD group (SMD=0.67, 95%CI [0.26, 1.9]).

Sensory Seeking. The meta-analysis on sensory sensitivity included 15 studies (ADHD participants = 968, controls = 1183). Sensory seeking was significantly higher in the ADHD group compared with the control group (SMD = 1.23, 95% CI [0.48, 1.97]). Heterogeneity was high (I^2 = 97%). No difference in sensory-seeking behaviors was found

FIGURE 2 Forest Plot of Meta-analysis on Sensory Avoiding



Note: ADHD = attention-deficit disorder with or without hyperactivity; SMD = standardized mean difference. Please note color figures are available online.

between participants with ADHD and controls for the adult subgroup (SMD = 0.52, 95% CI [1.06, 2.10]) (Figure 4).

Subgroup analyses indicated a significant difference based on the risk of bias ($p < .01$), with only studies with low risk of bias studies showing a significant difference between groups; on the sensory tools ($p < .01$), with studies using AASP showing no difference; and on the exclusion of participants with ASD ($p = .02$), with no difference between group when the exclusion of ASD was unclear. No outliers were detected in leave-one-out sensitivity analysis. No publication bias was found on funnel plot visual inspection and the Egger test.

Meta-analyses: Sensory Modalities

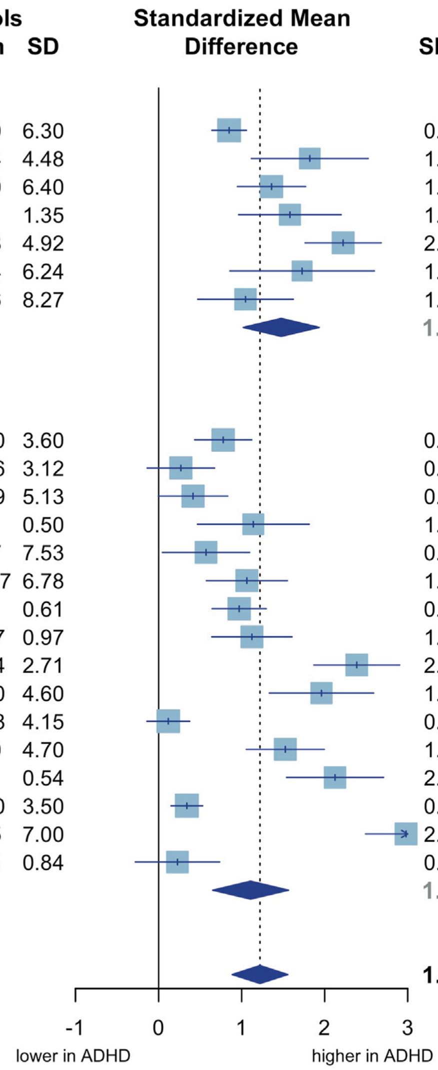
The results on sensory modalities are synthesized in Figure 5. The detailed results, sensitivity, and publication bias analyses are presented in Figures S34 to S64, available online. Patients with ADHD showed greater difficulties than the control population in tactile processing (k = 25, SMD = 0.85, 95% CI [0.65, 1.24], I^2 = 88%), visual processing (k = 16, SMD = 1.02, 95% CI [0.75, 1.30], I^2 = 77%), oral processing (k = 20, SMD = 0.78, 95% CI [0.50, 1.06], I^2 = 85%), auditory processing (k = 16, SMD = 1.40, 95% CI [0.95, 1.85], I^2 = 89%), and movement processing (k = 10, SMD = 1.28, 95% CI [0.56, 2.00], I^2 = 97%). There was no difference in body position processing between the ADHD and control groups (k = 4, SMD = 0.91, 95% CI [−0.16, 1.98], I^2 = 89%).

In subgroup analyses (Supplement 1, available online), differences between participants with ADHD and controls in tactile, visual, and auditory processing were found for children only. Movement and body position processing analyses did not include studies with an adult population. Adults and children with ADHD showed greater difficulties in oral processing compared with controls.

Heterogeneity was high in the different analyses. Its exploration of heterogeneity in subgroup analyses showed a significant difference based on risk of bias for visual processing ($p < .01$) and movement processing ($p = .02$) outcomes. When focusing on studies with a low risk of bias, the difference between groups concerning movement processing was no longer significant. Subgroup analyses showed a significant difference in heterogeneity based on sensory tools for visual processing ($p = .03$), auditory processing ($p = .01$), and movement processing ($p < .01$) outcomes. Meta-regression using age, year, or proportion of women as predictor was not significant for any of the sensory modality outcomes. No outliers were detected in leave-one-out

FIGURE 3 Forest Plot of Meta-analysis on Low Sensory Registration

Study	ADHD Total	ADHD Mean	ADHD SD	Controls Total	Controls Mean	Controls SD	SMD	95%-CI	Weight
adults									
Bijlenga et al. 2017 [43]	116	36.20	9.20	496	30.30	6.30	0.85	[0.64; 1.06]	4.8%
Kamath et al. 2020 [48]	23	42.83	10.18	22	28.14	4.48	1.82	[1.12; 2.53]	3.9%
Ohta et al. 2020 [49]	55	39.10	9.20	58	28.30	6.40	1.36	[0.95; 1.77]	4.5%
Adra et al. 2021 [50]	25	6.44	2.29	29	3.48	1.35	1.58	[0.96; 2.20]	4.1%
Grinblat et al. 2022 [53]	69	38.98	7.10	52	24.98	4.92	2.22	[1.76; 2.68]	4.4%
Schramm et al. 2023 [58]	15	38.20	6.20	14	27.14	6.24	1.73	[0.86; 2.60]	3.6%
Martinez-Gonzalez et al. 2024 [26]	15	20.93	9.64	76	11.96	8.27	1.05	[0.47; 1.62]	4.2%
Random effects model	**318**			**747**			**1.48**	**[1.02; 1.94]**	**29.5%**
Heterogeneity: I^2 = 84%, τ^2 = 0.2008, p < 0.01									
children									
Dunn and Bennett 2002 [34]	70	-37.70	7.90	70	-42.50	3.60	0.78	[0.43; 1.12]	4.6%
Yochman et al. 2004 [35]	48	-34.09	5.24	46	-35.26	3.12	0.27	[-0.14; 0.67]	4.5%
Miller et al. 2012 [38]	37	-24.84	11.98	57	-28.39	5.13	0.41	[-0.00; 0.83]	4.5%
Lin and al. 2013 [39]	20	0.43	0.89	20	-0.41	0.50	1.14	[0.47; 1.81]	4.0%
Lufi and al. 2014 [40]	30	18.60	8.10	28	14.07	7.53	0.57	[0.04; 1.10]	4.3%
Shimizu et al. 2014 [41]	37	-109.76	11.61	37	-119.97	6.78	1.06	[0.57; 1.55]	4.4%
Little and al. 2018 [45]	78	2.09	0.80	84	1.40	0.61	0.97	[0.64; 1.30]	4.6%
Mimouni-Bloch et al. 2018 [46]	38	-24.03	6.88	39	-29.57	0.97	1.12	[0.64; 1.61]	4.4%
Jegadeesanet al. 2020 [47]	50	-17.46	4.19	50	-25.94	2.71	2.39	[1.87; 2.90]	4.3%
Dellapiazza et al. 2021 [51]	28	-59.50	8.00	31	-72.30	4.60	1.96	[1.33; 2.59]	4.1%
Darnal et al. 2023 [55]	100	-23.28	4.47	139	-23.78	4.15	0.12	[-0.14; 0.37]	4.7%
Panda et al. 2023 [56]	66	43.60	5.80	33	35.20	4.70	1.53	[1.06; 2.00]	4.4%
Rani et al. 2023 [57]	38	37.66	9.88	34	22.21	0.54	2.12	[1.54; 2.71]	4.2%
Schulz et al. 2023 [59]	317	-28.00	6.00	163	-29.80	3.50	0.34	[0.15; 0.53]	4.8%
Fabio et al. 2024 [60]	69	48.23	5.20	69	29.75	7.00	2.98	[2.49; 3.47]	4.4%
Mohammed et al. 2024 [61]	30	-2.20	0.90	30	-2.40	0.84	0.23	[-0.28; 0.73]	4.3%
Random effects model	**1056**			**930**			**1.11**	**[0.65; 1.56]**	**70.5%**
Heterogeneity: I^2 = 93%, τ^2 = 0.6758, p < 0.01									
Random effects model	**1374**			**1677**			**1.22**	**[0.89; 1.56]**	**100.0%**
Heterogeneity: I^2 = 92%, τ^2 = 0.5450, p < 0.01									
Test for subgroup differences: χ^2_1 = 1.68, df = 1 (p = 0.19)									



Note: ADHD = attention-deficit/hyperactivity disorder, SMD = standardized mean difference. Please note color figures are available online.

sensitivity analysis. No publication bias was found in the different funnel plot visual inspections and Egger tests (Supplement 1, available online).

Meta-analyses: Binary Outcomes

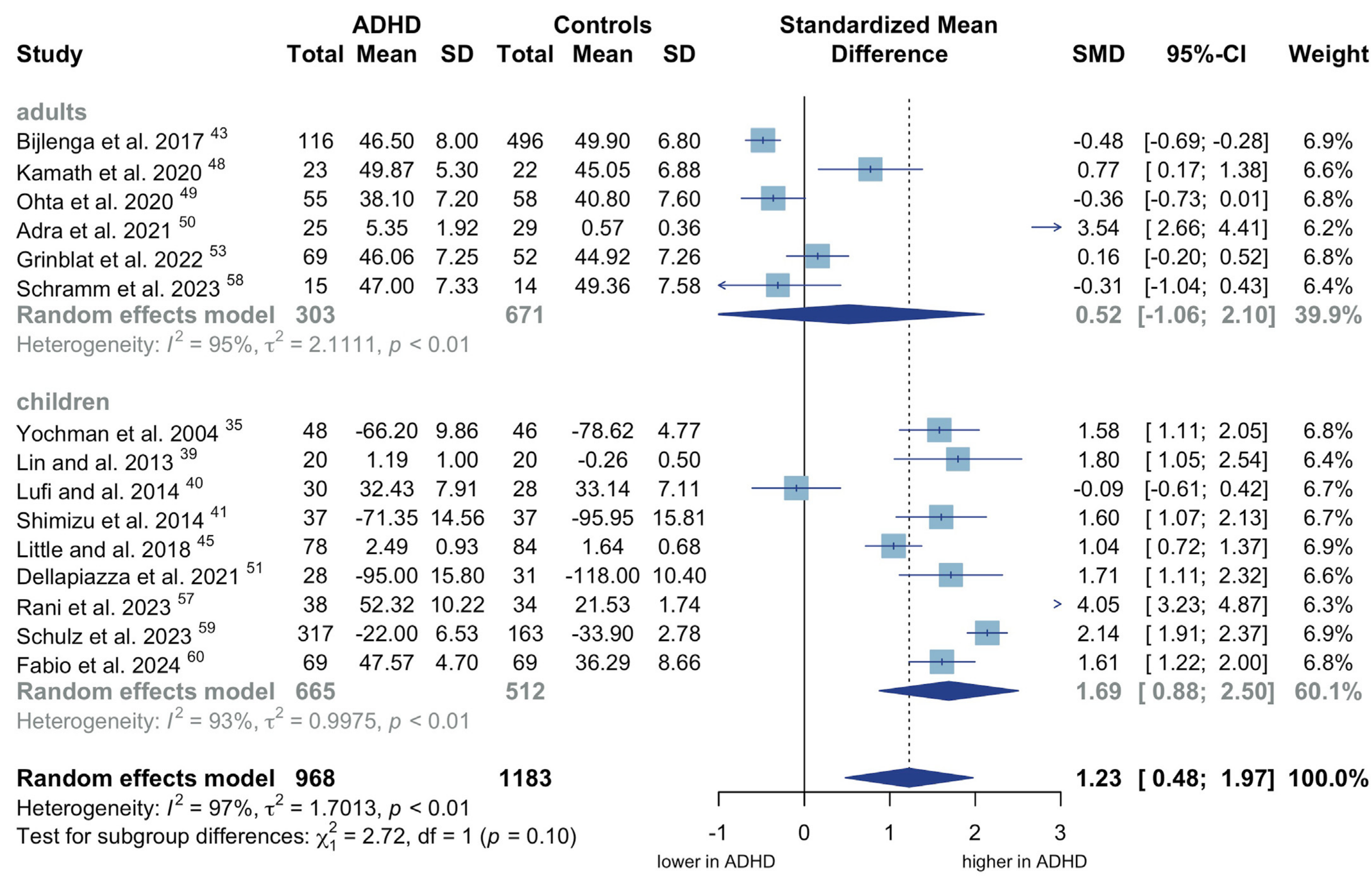
Hypersensitivity. The meta-analysis on hypersensitivity included 9 studies (ADHD participants = 372, controls = 753). The ADHD group had an increased risk of hypersensitivity (OR = 9.0, 95% CI [2.92, 27.71]) in both children and adults. Heterogeneity was moderate (I^2 = 61%) (Figure S65, available online). The funnel plot suggested a publication bias (Figure S66, available online). The adjusted result with the trim-and-fill procedure still favored an increased risk of hypersensitivity in ADHD (OR = 7.73, 95% CI [2.57, 23.24]). We did not explore the heterogeneity for this outcome due to paucity of studies.

Hyposensitivity. The meta-analysis on hyposensitivity included 5 studies (ADHD participants = 284, controls = 664). The ADHD population had an increased risk of hyposensitivity (OR = 9.71, 95% CI [2.80, 33.61]). Heterogeneity was moderate (I^2 = 43%). This difference was observed only in adults in the subgroup analyses (Figure S67, available online). We did not explore heterogeneity and publication bias for this outcome given the limited number of studies.

DISCUSSION

This is the first systematic review and meta-analysis to our knowledge exploring the association between ADHD and atypical SPP. Using data from 31 studies, we found that compared with controls, individuals with ADHD had

FIGURE 4 Forest Plot of Meta-analysis on Sensory Seeking

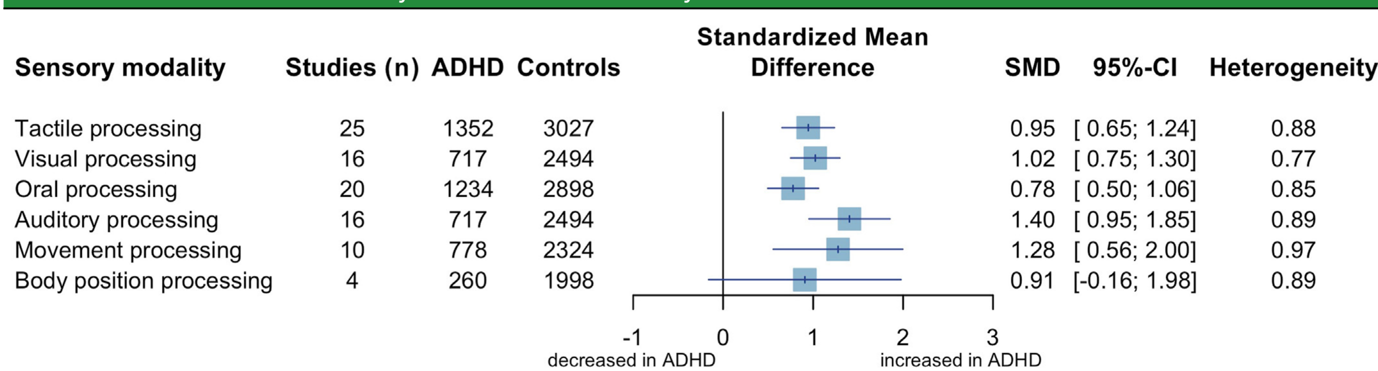


Note: *ADHD = attention-deficit/hyperactivity disorder; SMD = standardized mean difference. Please note color figures are available online.*

significantly higher levels of atypical SPP in 4 sensory modulation domains (sensory sensitivity, sensory seeking, low registration, and sensory avoiding), although sensory avoiding was not different between groups after adjustment using the trim-and-fill procedure.

Sensory sensitivity and low registration were different between groups in both adults and children. Nevertheless, sensory seeking did not differ between the ADHD and control groups in the adult studies subgroup. This variability may be due to the inconsistent conceptualization of sensory

FIGURE 5 Forest Plot of Meta-analysis Results for the Sensory Modalities



Note: *The detailed forest plots for each sensory modality meta-analysis are presented in Supplement 1, available online. ADHD = attention-deficit/hyperactivity disorder; SMD = standardized mean difference. Please note color figures are available online.*

seeking across different studies. Scales for young children focus on intense sensory exploration, whereas adult questionnaires, such as AASP, address personal sensory preferences.[14] This also raises the question of overlap in the symptoms between SPP and ADHD. The higher atypical SPP in the ADHD group may be explained, at least for some domains, by this overlap.[23,62] For example, on the sensory profile, participants with a high level of sensory-seeking behaviors often touch objects and tap their pencils in a way that increases the sensory input and stays alert. This mechanism has been frequently described in ADHD (hyperactivity). Therefore, it may be difficult to differentiate hyperactivity symptoms from sensory seeking. As hyperactivity symptoms tend to decrease with age, it is also possible that adult patients with ADHD present with fewer sensory-seeking behaviors. However, our meta-regression on age was not significant for this outcome, making it difficult to draw conclusions.

Low registration was moderated by age, with an increasing difference between individuals with ADHD and controls as age increased. This result is somewhat surprising, as the opposite trend has been described for ASD.[14,63] As inattention could reduce the perception of sensory stimuli and increase low registration scores, one hypothesis could be that in the younger population, certain contextual factors, such as the presence of parents, may naturally enhance children's attention toward stimuli. Another hypothesis could be that due to a longer history of ADHD and therefore the development of adaptive strategies, adults could filter sensory stimuli more effectively, leading to an increase in the low-registration domain.

Concerning sensory modalities, compared with the control group, participants with ADHD had a higher level of atypical SPP in 4 sensory discrimination domains/modalities (tactile, visual, auditory, oral, and movement). No difference was found in body position processing (or proprioception); however, this analysis included only 3 studies, so further replication is needed.

Our results on sensory modalities can be explained by shared neurophysiological pathways between ADHD and SPP, particularly involving disruptions in sensory integration systems. Deficits in white matter integrity in key tracts responsible for sensory integration can contribute to multisensory impairments.[64] A recent meta-analysis described alterations in the splenium and the body of the corpus callosum in ADHD, and these alterations could contribute to sensory processing difficulties.[65] Additionally, dopamine dysregulation, a hallmark of ADHD, can impair sensory gating and filtering mechanisms, further contributing to sensory discrimination challenges. This hypothesis suggests that treatment with psychostimulants may offer potential benefits for regulating sensory processing.[66]

When separating studies on adult and child populations, no difference between participants with ADHD and controls was found in adults concerning tactile, visual, and auditory processing. However, only 2 studies analyzed these outcomes and presented high between-study heterogeneity. More studies are therefore needed to reach conclusions on these specific domains in adult populations.

Considering the binary outcomes, individuals with ADHD, either adults or children, had a higher risk of being hypersensitive and hyposensitive. These analyses had a lower level of heterogeneity. This result is not surprising given the differences between patients with ADHD and controls across various sensory quadrants. Furthermore, this binary outcome demonstrates that clear distinctions between the groups remain even when focusing solely on individuals with extreme deviations from the norm. This underscores that these hypersensitivity and hyposensitivity patterns in ADHD represent an important clinical issue, complementing the significant differences already observed in continuous sensory scores.

More generally, our findings illustrate the complexity of sensory processing difficulties, with some individuals exhibiting both hypersensitivity and hyposensitivity, depending on the specific sensory modality. For instance, a person may be hypersensitive to auditory stimuli and hyposensitive to tactile input. This coexistence and the atypical sensory patterns across the 4 sensory quadrants reflect the heterogeneity of sensory profiles in ADHD, where sensory processing difficulties are not uniformly distributed but manifest as unique combinations of strengths and challenges across modalities.

This systematic review and meta-analysis has several strengths. We included studies with a clinical diagnosis of ADHD rather than ADHD symptoms to ensure that the results were pertinent to this clinical population. We included all validated sensory processing questionnaires to enable generalizability. Our work should also be considered in light of some limitations.

Concerning the limitations of the primary studies included in our systematic review, substantial methodological heterogeneity was observed, and a few studies were rated as having a low risk of bias. We could not retrieve missing data for several studies even after contacting the corresponding authors, preventing us from processing all preplanned sensitivity analyses. The presence of ADHD or another neurodevelopmental disorder was not systematically verified in the control groups, and some studies did not assess comorbidities or ADHD medications. We were unable to test the impact of medication, severity of ADHD, and type of ADHD, although these factors could be potential moderators of sensory processing. Information on IQ was frequently missing in 30% of the studies; however, no significant differences were observed between the subgroups in the IQ assessment subgroup analysis. The sample size of the included studies was often small and not defined a priori. Information on ethnicity was reported in only 5 studies (17%), which limits the generalizability of our results across diverse populations.

Most of our analyses found high heterogeneity, limiting our confidence in the results. Multiple subgroup and meta-regression analyses were conducted to explore this heterogeneity, but we did not find any specific explanation.

Concerning the limitations of the systematic review and meta-analysis itself, as stated above, we wanted to synthesize sensory processing constructs across multiple tools; therefore, we created a classification with an expert in the field. This classification could nevertheless introduce variability and bias the results beyond what we could identify in this meta-analysis.

Suspicion of publication bias emerged from the sensitivity analyses on several outcomes (sensory avoiding, low registration, hypersensitivity). We used an adjustment method to correct this bias.

The findings from this meta-analysis strongly indicate that both children and adults with ADHD are more likely to experience atypical SPP than the general population. Currently, the main guidelines for ADHD management (ie, National Institute for Health and Care Excellence [NICE] guidelines, American Academy of Pediatrics [AAP], American Academy of Child and Adolescent Psychiatry [AACAP] practice parameters[67-69]) do not include specific information on associated SPP. Given the significant functional impact of atypical SPP, early identification and targeted interventions are crucial to improve the overall prognosis of individuals with ADHD. Importantly, assessing SPP in individuals with ADHD is relatively straightforward due to the availability of validated assessment tools, making it easier for clinicians to identify and address these issues.

The effectiveness of sensory-based interventions for atypical SPP remains a subject of debate. Whereas some studies have suggested potential benefits, available studies present important methodological limitations, such as insufficient samples or nonrandomized assessment.[70] Lang *et al.*[71] reviewed sensory-based treatments and reported mixed results: 3 studies suggested effectiveness, 8 found mixed outcomes, and 14 found no significant benefits. Importantly, most of these studies evaluated isolated sensory procedures (eg, weighted vests, sensory brushing) rather than comprehensive, multicomponent approaches. Due to the current lack of solid evidence supporting direct therapeutic interventions, some in the field have highlighted the importance of applying sensory processing knowledge to make practical modifications in daily routines and environments, thereby enhancing accessibility and alleviating sensory-related difficulties.[72]

Crucially, the purpose of assessing SPP in individuals with ADHD is not solely to categorize them as normal or pathological. Instead, the goal is to better understand their unique functional profiles, including their strengths and weaknesses, and to leverage this understanding to develop comprehensive, individualized interventions. SPP assessments can provide clinicians and caregivers with valuable insights into how to support individuals by building on their strengths and addressing their sensory challenges in meaningful ways. Beyond identification, clinicians can guide patients in adapting their environments to better manage sensory sensitivities, such as using noise-reduction headphones for patients with high auditory sensitivity, as well as advocate for inclusive policies, such as quiet hours in supermarkets. Additionally, understanding one's sensory processing profile through such assessments can empower individuals with ADHD to engage in self-adaptation strategies, thereby enhancing their ability to cope with and mitigate the impact of SPD on their daily lives. By integrating these insights, clinicians may more effectively offer tailored interventions that could significantly enhance outcomes.

SPP has been proposed as a translational model in the Research Domain Criteria framework to better understand ASD.[73,74] These research efforts could be extended to ADHD, with SPP representing a novel avenue for advancing our understanding of the disorder and its associated comorbidities.

To fully realize the potential of this emerging field, future studies should prioritize larger, well-defined cohorts of ADHD and control participants, with careful attention paid to variables such as medication status, IQ, and comorbid conditions. Longitudinal studies, in particular, would be essential for examining the developmental trajectory of sensory processing in ADHD across the life span. Studies on the prevalence of atypical SPP could provide valuable insights into the extent and significance of sensory difficulties in ADHD. Additionally, studies comparing individuals with ADHD and other clinical groups would help to better understand the specificity of this association.

CRediT authorship contribution statement

Lucie Jurek: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Arnaud Duchier:** Writing – review & editing, Data curation. **Christophe Gauld:** Writing – review & editing, Data curation. **Léonie Hénault:** Writing – review & editing, Methodology. **Caroline Giroudon:** Writing – review & editing, Software, Data curation, Conceptualization. **Pierre Fourneret:** Writing – review & editing. **Samuele Cortese:** Writing – review & editing, Writing – original draft, Supervision. **Mikail Nourredine:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization.

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