Journal of Psychiatric Research 151 (2022) 173–180

Contents lists available at ScienceDirect

Journal of Psychiatric Research

journal homepage: www.elsevier.com/locate/jpsychires

Sensory processing difficulties in psychiatric disorders: A meta-analysis

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ARTICLE INFO

Keywords:
Sensory processing
Sensory processing disorder
Mental health
Psychiatric disorders
Psychopathology

ABSTRACT

In clinical practice, many individuals with psychiatric disorders report difficulties in sensory processing, including increased awareness or sensitivity to external stimuli. In this meta-analysis, we examined the sensory processing patterns of adolescent and adult individuals with a broad spectrum of different psychiatric conditions. A systematic search in various databases resulted in the inclusion of 33 studies (N = 2008), all using the Adolescent/Adult Sensory Profile (AASP). By comparing diagnostic subgroups to the corresponding reference group of the AASP, we detected a general pattern of sensory processing, indicating elevated levels of low registration, sensory sensitivity and sensory avoiding and lowered sensory seeking behavior in patients with different types of psychiatric disorders. The majority of effect sizes were large to very large. In conclusion, sensory processing difficulties can be considered as a non-specific transdiagnostic phenotype associated with a broad spectrum of psychiatric conditions. Further research into the relevance and role of sensory processing difficulties in psychiatric disorders may improve long-term prognosis and treatment.

1. Introduction

Many individuals with psychiatric disorders report difficulties in sensory processing in clinical practice, including increased awareness or sensitivity to external stimuli like sounds, lights, or smells. The understanding of sensory processing and sensory processing difficulties developed and evolved over the years, initially and primarily within the field of occupational therapy. The concept of sensory processing was initially developed by Jean Ayres in 1963. She established the term *sensory integration* (Ayres, 1963) and advanced the understanding of how humans receive, process and use sensory information. Ayres developed theories about the consequences of difficulties in sensory integration and introduced a therapy to improve sensory perceptual abilities, self-regulation, motor skills, and praxis (Ayres, 1972). This work represents an important development in occupational therapy which has contributed to the current standards in sensory processing theory and practice. In 1997, Winnie Dunn postulated her Model of Sensory Processing (Dunn, 1997). This model is based on two continua: the neurological threshold continuum and the behavioral response continuum. The neurological threshold continuum ranges from *low* to *high,* the behavioral response continuum ranges from *accordance* to *counteraction*. A low neurological threshold indicates that a person's neurons fire and provoke a reaction when exposed to low intensity stimuli, whereas a high neurological threshold indicates that stimuli of higher intensity are needed to provoke the same neurological reaction. Behavior in response to incoming sensory information can be in accordance with the neurological threshold, for instance in case of stimuli seeking when the threshold is high. Alternatively, counteracting can result when stimuli are avoided in case of a low threshold to prevent becoming overwhelmed. The interaction of the neurological threshold and the behavioral response results in four quadrants known as the patterns of sensory processing: low registration, sensory seeking, sensory sensitivity, and sensory avoiding (Brown et al., 2001; Dunn, 1997).

One of the most prominent manifestations of sensory problems is in autism spectrum disorders (ASD). Several studies show that sensory processing patterns in the majority of individuals with ASD differ from typically developing controls (Crane et al., 2009; Kern et al., 2006; Tomchek and Dunn, 2007). This applies to both children (Leekam et al., 2007) and adults (Crane et al., 2009). In fact, previous research indicates that more than 90% of children with ASD experience sensory

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https://doi.org/10.1016/j.jpsychires.2022.04.020
Received 15 November 2021; Received in revised form 24 March 2022; Accepted 18 April 2022
Available online 21 April 2022

abnormalities (Leekam et al., 2007). In the most recent version of the Diagnostic and Statistical Manual of Mental Disorders, these sensory processing difficulties have been incorporated in the diagnostic criteria for ASD (American Psychiatric Association, 2013). However, in other mental disorders, sensory processing difficulties receive far less attention. Occupational therapists increasingly report of persons with sensory processing difficulties as a separate, independent clinical phenomenon, which has led to the recommendation to include an independent sensory processing disorder (SPD) in classification systems (Miller et al., 2007). Other clinicians question whether sensory processing is part of an independent disorder, is a transdiagnostic marker of several (neurodevelopmental) disorders or part of typical behavioral development (Zimmer and Desch, 2012). How sensory processing difficulties relate to the broad spectrum of psychopathology other than neurodevelopmental disorders is largely unknown.

Indeed, previous research indicates that sensory processing abnormalities might not be restricted to ASD. Pfeiffer et al. (2014) explored a heterogeneous sample of 95 adults with different serious mental illnesses, such as schizophrenia-spectrum disorders, major depressive disorder and bipolar disorder and compared their sensory processing patterns to typically developing peers. More recently, Brown et al. (2020) reviewed the results of five studies focusing on sensory processing of participants with different mental illnesses, including obsessive-compulsive disorder, schizophrenia, bipolar disorder, depressive disorder, 'early psychosis' and posttraumatic-stress disorder. Although results of these studies indicate that sensory processing patterns of individuals with mental health problems differ from those of healthy individuals, it remains unknown whether these sensory processing difficulties could form a transdiagnostic factor. To further explore and expand upon these findings, we aimed to systematically analyze the full body of research on the association between patterns of sensory processing difficulties and psychiatric disorders in adolescent and adult populations.

2. Methods and materials

Several methods are available for measuring sensory processing: that is, self- and proxy-report questionnaires, psychophysical methods, direct observation, qualitative interview methods, or neuroimaging/EEG (DuBois et al., 2017). In order to collect mutually comparable quantitative data, we limited our meta-analysis to self- and proxy-report questionnaires. Selection of candidate questionnaires was based on DuBois et al. (2017). All questionnaires not developed for specific diagnostic groups and available for use in adolescent and adult populations were selected: Adolescent/Adult Sensory Profile (Brown and Dunn, 2002), Sensory Over-Responsivity Scales (Schoen et al., 2008), Sensory Perception Quotient (Tavassoli et al., 2014) and Auditory Attention and Discomfort Questionnaire (Dunlop et al., 2016).

Peer-reviewed articles in English language of empirical studies in which one or more of these four questionnaires were used to assess sensory processing preferences in participants with a psychiatric disorder were considered as eligible for our meta-analysis. Means and standard deviations for all subscales were reported or requested from the corresponding author. In case of multiple articles using the same or partly the same dataset, the manuscript that reported the most complete dataset was selected. The following databases were included in our search query: Embase, Medline, Cochrane CENTRAL, Web of Science, PsychINFO, CINAHL, and Google Scholar (top 500 relevant references). The search was last executed on March 4th 2021. Below we present the electronic search strategy as applied in Embase. Electronic search strategies for all other databases are included in the supplementary documents.

((((AASP OR SPQ OR AADQ) AND (sensor*)) OR ((adult* OR adolesc*) NEAR/3 (sensor*) NEAR/3 (profil*)):ab,ti,kw) OR ((('sensorimotor integration'/de OR 'mental overstimulation'/de OR 'developmental coordination disorder'/de OR 'visuomotor coordination'/de OR (((sensor* OR visu*-motor* OR visu*-percept* OR multisensor*) NEAR/6 (integrat* OR modulat* OR processing OR incongruen* OR sensitivit* OR discriminat* OR coordinat* OR dysfunct* OR profile* OR seeking OR avoid* OR overrespons* OR underrespons* OR over-respons* OR under-respons* OR overstimul* OR understimul* OR over-stimul* OR under-stimul*)) OR (multisensor* NEAR/3 percep*)):ab,ti,kw) AND ((profil*):ab,ti,kw) AND ('questionnaire'/de OR 'interview'/exp OR (questionnaire* OR interview*):ab,ti,kw)) OR ((((sensor*) NEAR/3 (over-responsivit* OR overresponsivit*) NEAR/3 (scale*)) OR ((sensor*) NEAR/3 (perception*) NEAR/3 (quotient*)) OR ((audit*) NEAR/3 (attent*) NEAR/3 (distress*) NEAR/3 (question*))):ab,ti,kw)) NOT ('child'/exp NOT ('adult'/exp OR 'adolescent'/de)) NOT ((animal/exp OR animal*:de OR nonhuman/de) NOT ('human'/exp))

The selection process is summarized in Fig. 1. The selection process included screening for article type, publication in a peer-reviewed journal, language, the use of the selected instruments and the inclusion of participants with a diagnosed psychiatric disorder. Remaining articles were assessed for data availability and overlapping samples. The total amount of 1272 references was screened on eligibility for inclusion in the meta-analysis. A random sample of 20 percent (n = 255) was screened by a second independent researcher, resulting in a very good level of inter-rater reliability (*Cohen's kappa* = .896). In sum, all studies in non-neurodevelopmental populations used the AASP, except for one study which used the SPQ in tic disorders (Isaacs et al., 2020). Consequently, we decided to only include studies that used the AASP in our meta-analysis. We extracted information on (reported or obtained) means and standard deviations for (sub)scales, sample recruitment and characteristics of the patient group(s), including information about comorbidity, the number of participants in each patient group and the age of participants, to make sure that the correct AASP norm group was applied.

Samples were grouped in accordance with section II of DSM5 (American Psychiatric Association, 2013). Inclusion criteria applied in individual studies were decisive for group classification. Because of the relatively large number of studies found, we decided to further distinguish between specific neurodevelopmental disorders. Results were therefore calculated and presented separately for the following diagnoses and diagnosis groups: autism spectrum disorder (with and without comorbid intellectual disability), attention-deficit/hyperactivity disorder, specific learning disorder, schizophrenia spectrum and other psychotic disorders, bipolar and related disorders, depressive disorders, obsessive-compulsive and related disorders, trauma and stressor-related disorders, somatic symptom and related disorders, substance-related and addictive disorders, and neurocognitive disorders. Also, we grouped data into separate age groups where applicable, in accordance with AASP reference group data: adolescents, adults and elderly. Overall group size and pooled means and standard deviations of each AASP raw quadrant score were calculated for each group (Higgins et al., 2019). We compared the aggregated clinical group data with the reference group data, as published in the AASP manual (Brown and Dunn, 2002) with multiple Welch's t-tests in IBM SPSS version 25 (Delacre et al., 2017). The *t*-statistic and *p*-value were reported, tested at a two-sided alpha-level of .05. Effect sizes were expressed in Cohen's *d*, reported and visualized with 95 percent confidence intervals, and interpreted using the Sawilowsky (2009) guidelines. Since most articles report the data of interest to our meta-analysis as secondary measurements or as part of descriptive characteristics, we expect the risk of bias in individual studies to be limited, including the risk of publication bias.

3. Results

A total of 33 articles (N = 2008) was included in this meta-analysis. Descriptive statistics extracted from each included reference are presented in Table 1. Pooled means and standard deviations for each of the AASP raw quadrant scores on subgroup level are presented in Table 2.

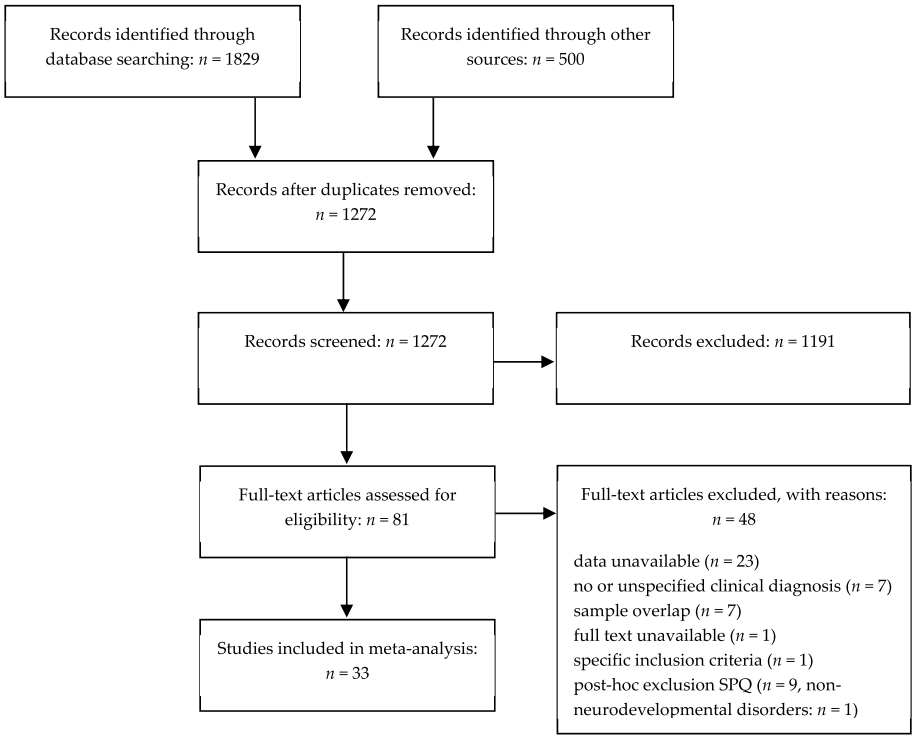

Fig. 1. Reference selection process after database search queries.

Almost all AASP quadrant scores across the various diagnostic groups differ from the reference data, as evidenced by the majority of significant Welch's *t* tests. Sensory seeking is lower in all diagnosis-based subgroups, with the largest effects for autism spectrum disorder with intellectual disability, depressive disorders, trauma and stressor-related disorders and neurocognitive disorders. Differences regarding sensory sensitivity and sensory avoiding are statistically significant for all diagnosis-based subgroups, except neurocognitive disorders, in comparison with the AASP reference group. Raw quadrant scores for sensory sensitivity and sensory avoiding were higher for diagnostic subgroups than reference group scores, except for autism spectrum disorder with intellectual disability. Finally, low registration was elevated in most diagnostic groups, although no statistically significant differences were found in bipolar- and related disorders, depressive disorders and neurocognitive disorders. Calculated effect sizes of each comparison are visualized in Fig. 2. In general, the majority of the effect sizes were large to very large.

4. Discussion

In this meta-analysis of 33 studies, we compared patients with various types of psychiatric disorders to corresponding AASP reference groups and detected a general pattern of sensory processing difficulties. Overall, patients showed elevated levels of low registration, sensory sensitivity and sensory avoiding and lowered sensory seeking behavior. This pattern appeared in all diagnostic subgroups and age groups, except for adult patients with ASD and intellectual disability and for elderly patients with neurocognitive disorders. Effects varied from small to very large. Our results confirm earlier findings by Pfeiffer et al. (2014), indicating differences between the sensory processing patterns of individuals with serious mental illnesses and typically developing peers. Furthermore, the patterns of sensory processing based on our results are comparable to the patterns detected in an earlier review of only five studies (Brown et al., 2020). We demonstrated these patterns in a broader spectrum of mental disorders, with aggregated data from a larger number of studies and presented detailed sample characteristics and effect sizes.

The underlying mechanisms explaining why individuals with psychiatric disorders share a broad pattern of sensory processing difficulties are still unclear. These difficulties might be a transdiagnostic factor, underlying psychopathology and crossing diagnostic borders. With the expanding neurobiological and neuroscientific initiatives in more recent psychopathological research, several transdiagnostic factors have been proposed, such as heart rate variability (Beauchaine and Thayer, 2015) and reward processing dysfunction (Whitton et al., 2015). Within these initiatives, the attention for the role of sensory processing seems to increase in recent years. The NIMH Research Domain Criteria (RDoC) initiative emphasizes the importance of integrating neuroscience and psychopathology, resulting in research projects with more objective domains and systems taking into account various biological and behavioral levels (Insel et al., 2010). Recently, researchers argued that sensory processing should be one of these domains (Harrison et al., 2019). Moreover, the EU recently funded the PRISM Project to develop a quantitative and biological approach to further our understanding of neuropsychiatric diseases and their treatment. One transdiagnostic key area the project will focus on is social withdrawal, taking working memory, attention and sensory processing into account as possible covariates (Kas et al., 2019). In sum, although scientific attention for the question whether sensory processing difficulties are a transdiagnostic factor for psychopathology increased in recent years, a decisive answer is unavailable to date. Our analysis provides robust results that point towards a transdiagnostic perspective.

An explanation for these similar patterns of sensory difficulties in a broad range of mental disorders may be found by looking at sensory processing in even more detail. Coarse-meshed item analysis of the AASP leads to several conceptual uncertainties with regard to the

Table 1
Descriptive statistics extracted or received from references included in the meta-analysis.

Reference	Clinical diagnosis or diagnosis group (DSM5)						Reference group	Low Registration		Sensory Seeking		Sensory Sensitivity		Sensory Avoiding	
		Total	Male	Female	*M* Age	*SD* Age		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Bashapoor et al. (2015)	Substance-Related and Addictive Disorders	36	36	0	30.54	7.58	Adults	38.05	9.31	40.27	9.04	47.88	7.79	39.63	8.91
Bijlenga et al. (2017)	Attention-Deficit Hyperactivity Disorder	116	72	44	32.00	10.20	Adults	36.20	9.20	46.50	8.00	40.90	9.20	36.60	10.60
van den Boogert et al. (2021)	Autism Spectrum Disorder	101	53	48	32.90	12.40	Adults	38.00	8.40	39.10	8.80	46.70	11.30	47.90	10.60
Brown et al. (2002)	Bipolar and Related Disorders	30	13	17	39.57	11.63	Adults	34.40	7.70	47.70	6.40	39.70	11.20	43.30	9.20
	Schizophrenia Spectrum and Other Psychotic Disorders	27	16	11	42.96	10.20	Adults	36.90	9.70	45.50	7.60	38.90	10.50	40.90	9.60
Buyuktaskin et al. (2021)	Autism Spectrum Disorder	30	23	7	13.20	2.04	Adolescents	34.07	8.25	40.80	7.60	38.50	9.28	39.90	9.23
Chung (2006)	Neurocognitive Disorders	33	8	25	85.24	8.53	Elderly	37.76	9.45	34.55	6.54	32.21	8.94	34.00	6.52
Clince et al. (2016)	Attention-Deficit Hyperactivity Disorder	28	18	10	NR	NR	Adults	40.64	8.74	44.89	8.21	44.18	8.97	41.32	9.37
	Autism Spectrum Disorder	27	22	5	NR	NR	Adults	42.81	7.96	40.26	6.43	46.63	10.12	45.63	9.78
Crane et al. (2009)	Autism Spectrum Disorder	18	10	8	41.78	15.24	Adults	42.56	9.28	39.44	8.15	45.00	10.05	46.17	11.87
Engel-Yeger (2014) [E]	Substance-Related and Addictive Disorders	145	112	28	33.89	9.79	Adults	33.78	8.52	46.39	9.15	39.79	9.24	39.97	9.86
Fukuyama et al. (2017)	Autism Spectrum Disorder	23	12	11	40.08	9.26	Adults	43.04	7.74	32.65	7.59	47.61	11.42	44.83	11.21
Gonthier et al. (2016)	Autism Spectrum Disorder with Intellectual Disability	148	104	44	32.98	8.82	Adults	34.59	7.89	33.78	7.64	30.61	7.33	30.84	9.58
Halperin and Falk-Kessler (2020) [A]	Schizophrenia Spectrum and Other Psychotic Disorders	17	9	8	36.53	10.09	Adults	37.63	10.50	46.06	9.78	39.24	11.09	43.65	11.39
Kamath et al. (2020)	Attention-Deficit Hyperactivity Disorder	23	9	14	21.87	1.98	Adults	42.83	10.18	49.87	5.30	43.04	8.74	39.70	7.04
Karhson and Golob (2016)	Autism Spectrum Disorder	12	8	4	22.50	4.10	Adults	43.67	8.16	46.83	8.14	45.00	9.07	45.58	8.27
Koirala et al. (2021)	Autism Spectrum Disorder	12	11	1	14.25	2.18	Adolescents	35.75	10.84	43.75	7.99	37.50	7.59	40.42	7.67
Kuno-Fujita et al. (2020)	Autism Spectrum Disorder	18	15	3	31.17	3.29	Adults	32.06	8.39	36.88	10.53	32.59	9.43	37.41	8.58
De la Marche et al. (2012)	Autism Spectrum Disorder	80	64	16	13.91	1.84	Adolescents	33.99	8.73	37.48	7.19	36.80	9.53	36.94	10.13
Mayer and Heaton (2014)	Autism Spectrum Disorder	19	15	4	40.23	11.33	Adults	43.42	10.41	43.79	8.29	47.16	10.19	45.21	9.54
Mayer (2017)	Autism Spectrum Disorder	42	28	14	35.07	12.38	Adults	40.95	9.33	41.83	9.55	46.19	9.87	46.62	8.34
McCarthy et al. (2017) [D]	Trauma and Stressor-Related Disorders	28	27	1	63.50	7.60	Adults	41.90	7.90	38.10	5.80	43.20	6.20	46.90	6.30
Myles et al. (2007) [B]	Autism Spectrum Disorder	94	NR	NR	14.97	NR	Adolescents	40.30	8.35	42.39	9.58	41.48	9.31	45.23	12.36
Ohta et al. (2020)	Attention-Deficit Hyperactivity Disorder	55	42	13	31.20	8.80	Adults	39.10	9.20	38.10	7.20	41.80	9.60	41.30	10.20
	Autism Spectrum Disorder	105	92	13	31.20	7.10	Adults	36.90	9.00	31.80	6.30	39.10	10.70	39.70	10.10
Pfeiffer et al. (2018) [A]	Autism Spectrum Disorder	50	23	27	32.66	12.40	Adults	44.40	8.60	40.74	8.22	48.16	10.31	50.60	11.43
Ranford et al. (2020)	Somatic Symptom and Related Disorders	44	10	34	42.60	15.40	Adults	40.00	10.60	43.20	8.30	46.30	11.50	45.50	10.70

(*continued on next page*)

Table 1 (*continued*)

Reference	Clinical diagnosis or diagnosis group (DSM5)						Reference group	Low Registration		Sensory Seeking		Sensory Sensitivity		Sensory Avoiding	
		Total	Male	Female	*M* Age	*SD* Age		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Rieke and Anderson (2009) [C]	Obsessive-Compulsive and Related Disorders	51	12	39	46.00	10.40	Adults	36.00	7.50	46.10	6.90	43.90	9.70	43.80	10.80
Serafini et al. (2016) [B]	Bipolar and Related Disorders	139	56	83	48.31	11.47	Adults	30.33	10.27	36.75	11.44	36.09	11.38	35.28	11.25
	Depressive Disorders	197	70	127	48.31	11.47	Adults	31.39	9.93	36.47	8.71	37.55	11.58	36.55	11.52
Sharfi and Rosenblum (2015)	Specific Learning Disorder	55	19	36	29.58	6.40	Adults	36.53	7.79	46.98	7.33	43.60	8.82	38.21	8.33
Stewart et al. (2016) [A]	Autism Spectrum Disorder	25	NR	NR	13.10	2.80	Adolescents	34.00	8.85	41.80	7.39	33.88	9.55	35.80	7.80
Syu and Lin (2018)	Autism Spectrum Disorder	70	46	24	27.80	5.00	Adults	41.60	8.60	43.60	8.10	43.20	9.70	45.90	8.20
Top et al. (2019) [B]	Autism Spectrum Disorder	24	19	5	24.47	6.14	Adults	39.83	7.14	52.69	6.54	44.91	10.11	48.75	9.46
Üçgül et al. (2017)	Schizophrenia Spectrum and Other Psychotic Disorders	40	30	10	41.10	10.48	Adults	36.55	9.19	42.95	9.75	39.00	9.70	41.00	9.30
Umesawa et al. (2020) [A]	Autism Spectrum Disorder	17	12	5	21.47	3.20	Adults	39.47	10.45	40.29	8.36	44.76	15.42	46.12	14.37
Zhou et al. (2020)	Schizophrenia Spectrum and Other Psychotic Disorders	29	9	20	14.69	1.47	Adolescents	41.52	8.94	41.97	8.61	41.93	9.34	41.31	8.47

NR = Not reported.
[A] Data received from corresponding author.
[B] AASP filled out by subgroup(s) of sample; sample characteristics based on total sample where available.
[C] Sample contained 10 participants without confirmed OCD.
[D] AASP data is extracted from pre-intervention measurements.
[E] Sample characteristics for sex contain missing cases.

interplay of social withdrawal, cognitive functioning and sensory processing. For instance, low registration could in part be related to or function as a measurement of neurocognitive problems, such as attention or concentration problems. In turn, it is known that neurocognitive problems are related to mental health problems (Trivedi, 2006). The DSM5 criteria of some disorders, like depression and post-traumatic stress disorder, also consist of neurocognitive problems (American Psychiatric Association, 2013). Similarly, items of the AASP sensory seeking subscale indicates the relevance of other concepts, such as anhedonia or social withdrawal, which seems intuitive as well. In case of sensory sensitivity, conceptual overlap seems less intuitive. However, sensory sensitivity might well be associated with the broad spectrum of mental health conditions, e.g. through stress sensitivity. Subjective stress is found to be positively associated with self-reported sensory sensitivity in several student populations (Benham, 2006; Gearhart and Bodie, 2012; Gerstenberg, 2012). In children with autism, sensory sensitivity was also found to be related to increased concentrations of cortisol (Corbett et al., 2009). Surprisingly, literature on this association is still scarce and evidence limited. In sum, sensory processing might be associated with mental health through conceptual overlap or as a proximal correlate.

Our study has some limitations. First, we restricted our meta-analysis to questionnaires, therefore not taking into account other diagnostic methods, such as psychophysical methods or (functional or structural) neuroimaging. Other types of measures may shed light on different aspects of sensory processing than were presented here. Unfortunately, incorporating these neurobiological measures or other qualitative assessments of sensory sensitivity into a quantitative meta-analysis was not feasible, but Hornix et al. (2019) narratively reviewed sensory circuit development in relation to risk gene mutations in neuropsychiatric disorders. Second, the AASP (Brown and Dunn, 2002) is the most frequently used method to assess sensory processing patterns in adolescent and adult populations of ASD patients (DuBois et al., 2017), as was confirmed by our detailed search methods. However, although the instrument is often used and demonstrates good psychometric properties, incorporation of only one questionnaire limits the impact of conclusions. Additionally, our results could be influenced by the, to some extent, limited representative quality of the reference group for the AASP in the general population. This reference group represents an overrepresentation of Caucasian participants from the Mid-Western parts of the United States of America, for which no data on social-economic status or intelligence were available (Brown and Dunn, 2002). On the other hand, most of the individual studies in our meta-analysis show a highly similar pattern of sensory processing. We deem it unlikely that the medium to very large effects in our results could be explained solely by issues with the AASP reference groups. However, future research on the validating the reference group's representativeness would be recommended.

In conclusion, sensory processing difficulties can be considered a transdiagnostic phenomenon associated with a broad spectrum of psychiatric conditions and these difficulties deserve both clinical and scientific attention. We invite the fields of psychiatry, psychology, occupational therapy, neuroscience, biology, and other fields involved to collaborate in future research to determine the relevance and role of

Table 2
Descriptive statistics per aggregated diagnosis-based subgroup with comparison to AASP reference group data.

Clinical diagnosis or diagnosis group	Reference group	Subgroups	Participants	Low Registration			Sensory Seeking			Sensory Sensitivity			Sensory Avoiding		
		K	N	M	SD	Cohen's d	M	SD	Cohen's d	M	SD	Cohen's d	M	SD	Cohen's d
Autism spectrum disorder	Adolescents	5	241	36.55	9.09	0.35	40.57	8.55	−1.01	38.57	9.61	0.53	40.60	11.29	0.79
				$t(431) = 3.70$,		$p < .001$	$t(402) = -10.42$,		$p < .001$	$t(431) = 5.62$,		$p < .001$	$t(410) = 8.54$,		$p < .001$
	Adults	13	526	39.98	9.12	1.23	39.33	9.46	−1.28	44.14	11.17	1.09	45.31	10.63	1.17
				$t(932) = 19.91$,		$p < .001$	$t(956) = -20.58$,		$p < .001$	$t(931) = 17.52$,		$p < .001$	$t(936) = 18.89$,		$p < .001$
Autism spectrum disorder with intellectual disability	Adults	1	148	34.59	7.89	0.65	33.78	7.64	−2.30	30.61	7.33	−0.41	30.84	9.58	−0.47
				$t(205) = 6.09$,		$p < .001$	$t(222) = -23.08$,		$p < .001$	$t(250) = -4.47$,		$p < .001$	$t(201) = -4.37$,		$p < .001$
Attention-deficit/ hyperactivity disorder	Adults	4	222	38.17	9.47	1.07	44.57	8.50	−0.72	41.76	9.24	0.99	38.68	10.22	0.49
				$t(310) = 11.34$,		$p < .001$	$t(354) = -8.25$,		$p < .001$	$t(362) = 11.36$,		$p < .001$	$t(327) = 5.40$,		$p < .001$
Specific learning disorder	Adults	1	55	36.53	7.79	0.97	46.98	7.33	−0.43	43.60	8.82	1.28	38.21	8.33	0.49
				$t(62) = 5.74$,		$p < .001$	$t(65) = -2.83$,		$p = .006$	$t(63) = 7.99$,		$p < .001$	$t(64) = 3.11$,		$p = .003$
Schizophrenia spectrum and other psychotic disorders	Adolescents	1	29	41.52	8.94	1.01	41.97	8.61	−0.83	41.93	9.34	1.04	41.31	8.47	1.14
				$t(34) = 4.55$,		$p < .001$	$t(38) = -4.32$,		$p < .001$	$t(33) = 4.38$,		$p < .001$	$t(34) = 5.02$,		$p < .001$
	Adults	3	84	36.88	9.52	0.97	44.40	9.12	−0.77	39.02	10.12	0.66	41.50	9.78	0.90
				$t(95) = 6.13$,		$p < .001$	$t(99) = -5.29$,		$p < .001$	$t(100) = 4.59$,		$p < .001$	$t(99) = 6.21$,		$p < .001$
Bipolar and related disorders	Adults	2	169	31.05	9.97		38.69	11.50	−1.36	36.73	11.40	0.35	36.70	11.31	0.25
				$t(214) = 0.93$,		$p = .351$	$t(210) = -11.98$,		$p < .001$	$t(221) = 3.21$,		$p = .002$	$t(218) = 2.29$,		$p = .023$
Depressive disorders	Adults	1	197	31.39	9.93		36.47	8.71	−1.81	37.55	11.58	0.43	36.55	11.52	0.23
				$t(260) = 0.76$,		$p = .150$	$t(296) = -19.42$,		$p < .001$	$t(266) = 4.30$,		$p < .001$	$t(262) = 2.24$,		$p = .026$
Obsessive-compulsive and related disorders	Adults	1	51	36.00	7.50	0.90	46.10	6.90	−0.56	43.90	9.70	1.30	43.80	10.80	1.20
				$t(57) = 5.25$,		$p < .001$	$t(61) = -3.76$,		$p < .001$	$t(57) = 7.27$,		$p < .001$	$t(55) = 5.96$,		$p < .001$
Trauma and stressor-related disorders	Adults	1	28	41.90	7.90	1.83	38.10	5.80	−1.74	43.20	6.20	1.25	46.90	6.30	1.69
				$t(29) = 7.64$,		$p < .001$	$t(31) = -10.38$,		$p < .001$	$t(32) = 7.77$,		$p < .001$	$t(31) = 9.98$,		$p < .001$
Somatic symptom and related disorders	Adults	1	44	40.00	10.60	1.45	43.20	8.30	−0.96	46.30	11.50	1.57	45.50	10.70	1.43
				$t(46) = 5.99$,		$p < .001$	$t(48) = -5.21$,		$p < .001$	$t(46) = 7.12$,		$p < .001$	$t(47) = 6.64$,		$p < .001$
Substance-related and addictive disorders	Adults	2	181	34.63	8.82	0.62	45.17	9.43	−0.62	41.40	9.52	0.94	39.90	9.66	0.66
				$t(249) = 6.08$,		$p < .001$	$t(252) = -6.19$,		$p < .001$	$t(269) = 9.78$,		$p < .001$	$t(260) = 6.75$,		$p < .001$
Neurocognitive disorders	Elderly	1	33	37.76	9.45		34.55	6.54	−1.58	32.21	8.94		34.00	6.52	
				$t(37) = 1.76$,		$p = .087$	$t(45) = -9.97$,		$p < .001$	$t(38) = -.98$,		$p = .331$	$t(45) = -0.81$,		$p = .936$

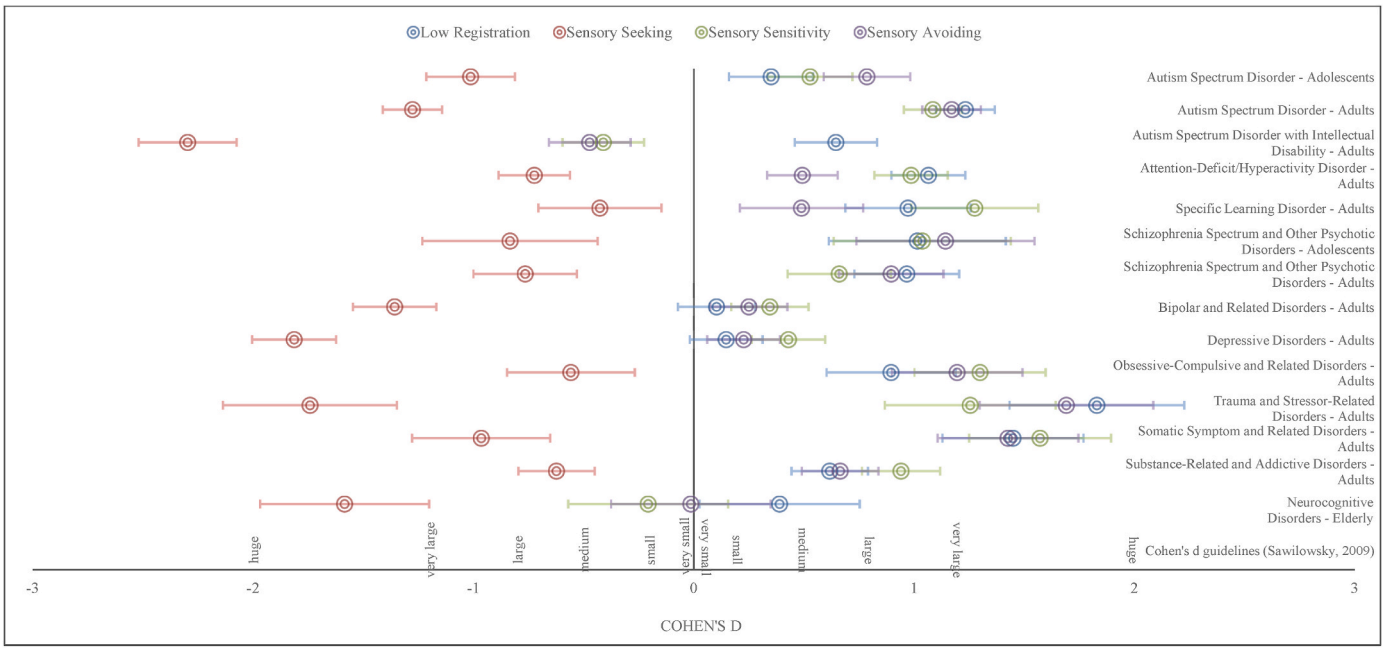

Fig. 2. Cohen's d effect sizes with 95% confidence intervals of Welch's *t*-test comparison of diagnosis-based subgroup with AASP reference group data.

sensory processing difficulties and investigate its causal mechanisms in the context of psychiatric disorders and, in particular, their implications for treatment.

Role of funding source

Financial support was provided by Stichting Vrienden van Oldenkotte, Deventer, the Netherlands (Grant: FORETECH). The sponsor had no involvement in study design, in the collection, analysis and interpretation of data, in the writing of the report, or in the decision to submit the article for publication.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors gratefully acknowledge the Erasmus MC Medical Library for their expert support in our search for relevant literature.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychires.2022.04.020.

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