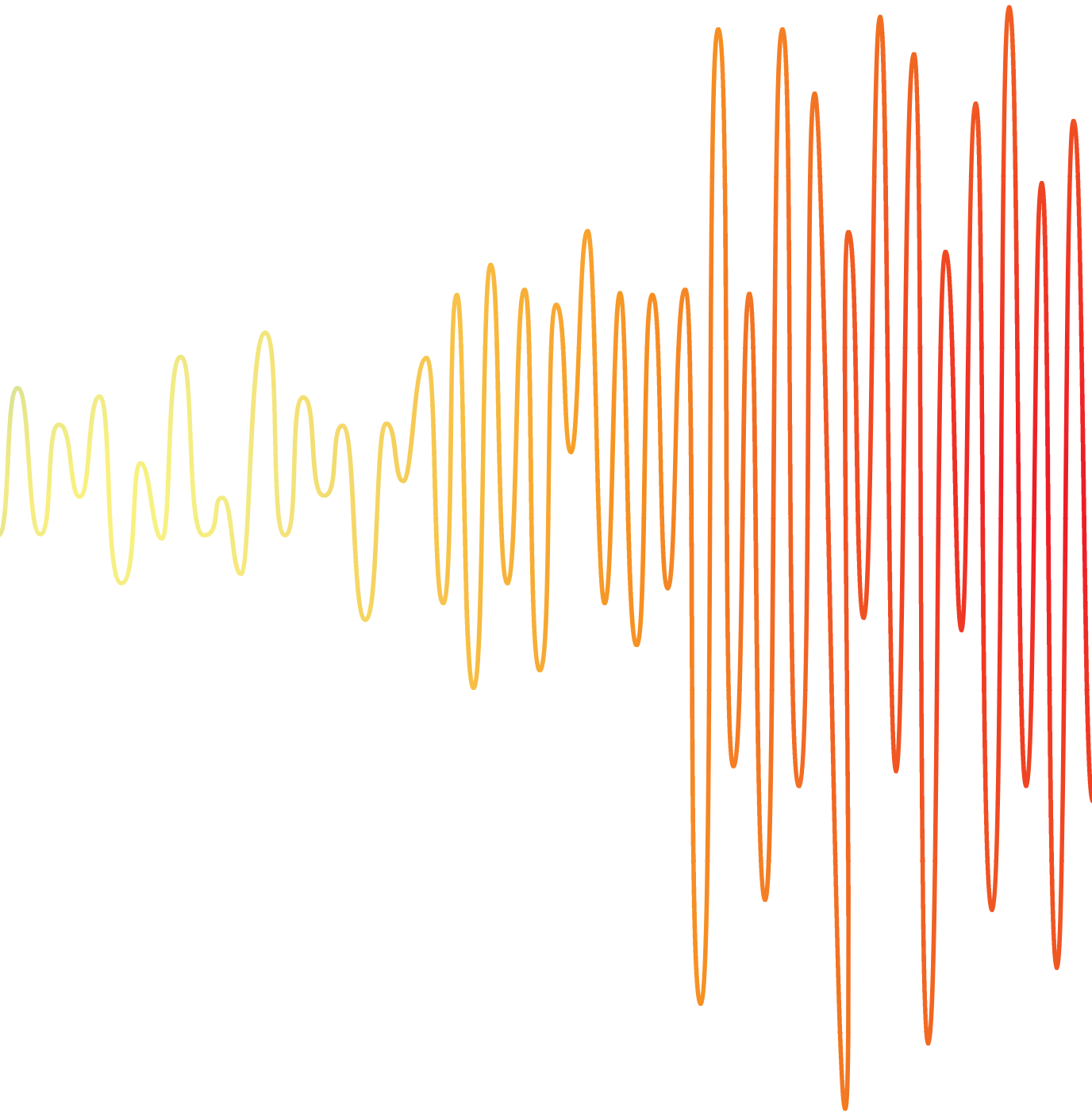
SENSORY PROCESSING AND PSYCHOPATHOLOGY

A FORENSIC PERSPECTIVE



FRANK VAN DEN BOOGERT

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Frank van den Boogert

The studies in this thesis were financially supported by: Stichting Vrienden van Oldenkotte, Deventer, the Netherlands.

Financial support for the printing of this thesis was provided by: Department of Psychiatry, Erasmus MC, Rotterdam, the Netherlands.

ISBN: 978-94-6458-994-8

Printed by: Ridderprint B.V.

Sensory Processing and Psychopathology
A forensic perspective

Sensorische prikkelverwerking en psychopathologie
Een forensisch perspectief

Proefschrift

ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag de
rector magnificus

Prof. dr. A.L. Bredenoord

en volgens besluit van het College voor Promoties.
De openbare verdediging zal plaatsvinden op

dinsdag 18 april 2023 om 15.30 uur

door

Franciscus Johannes Karel van den Boogert
geboren te Rotterdam.

Erasmus University Rotterdam

Promotiecommissie:

Promotor:	prof. dr. W.J.G. Hoogendijk
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CHAPTER ONE

General introduction

A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

Jim is a 24-year-old male in treatment for autism spectrum disorder, psychotic vulnerability and substance use disorder at a forensic psychiatric hospital. He was admitted to a Dutch Forensic Psychiatric Centre, under the Dutch Entrustment Act (TBS; terbeschikkingstelling) after he committed manslaughter, a crime for which he was held fully irresponsible. During his first weeks on the psychiatric ward, Jim reports to the nurses and social workers that he often feels overwhelmed by the sensory input he receives from his new environment, in particular the loud talking and yelling by his fellow inpatients, the music played on high volume in various rooms, the bright lights and the constant smell of cigarette smoke. Even though auditory and visual hallucinations have been reduced significantly as a result of antipsychotic use, Jim is often seen with wads of toilet paper in his ears and he prefers to withdraw to his room with the lights turned off for the most part of the day. Several times a week, Jim is subject to a urine drug test. Two of these tests were positive for the use of cannabis and alcohol. Jim has also been involved in several aggressive incidents towards personnel and other patients. To what extent could this aggressive behavior be explained by his sensory processing difficulties? Are these difficulties related to his substance use? How are these difficulties related to his complex psychopathology? Are there evidence-based interventions available in order to improve his processing of sensory stimuli?

Sensory processing difficulties

As in the case of Jim, sensory processing difficulties are reported by many individuals with psychiatric disorders in clinical practice. Sensory processing includes the receiving, modulating, integrating and organizing of sensory stimuli, and producing a behavioral response to these stimuli (Miller & Lane, 2000). It involves all information received through the various sensory modalities, for instance visual, auditory, olfactory, gustatory, tactile, vestibular, proprioceptive or interoceptive information. The study of difficulties in these sensory processes started within the field of occupational therapy and in particular by means of the groundbreaking work of Jean Ayres and Winnie Dunn. Ayres established the term sensory integration and advanced the understanding of how humans receive, process and use sensory information (Ayres, 1963). Dunn advanced this understanding with the Model of Sensory Processing (Dunn, 1997). This model presents the interaction of a neurological threshold continuum and a behavioral response continuum, resulting 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). Several methods are available for measuring sensory processing: for instance, self- and proxy-report questionnaires, psychophysical methods, direct observation, qualitative interview methods, or neuroimaging/EEG (DuBois et al., 2017). The Adolescent/Adult Sensory Profile (AASP) questionnaire provides the possibility to measure these patterns and, as a result, to assess sensory processing difficulties in daily functioning (Brown et al., 2001). It is the most frequently used instrument for these purposes in adolescents and adults with autism spectrum disorders (ASD; DuBois et al., 2017).

Sensory processing difficulties are highly prevalent in individuals with ASD. In fact, several studies demonstrate how sensory processing patterns differ from neurotypically developing controls in the vast majority of individuals with ASD (Crane et al., 2009; Kern et al., 2006; Tomchek & Dunn, 2007), with over 90 percent of children with ASD experiencing sensory processing difficulties (Leekam et al., 2007). In addition, sensory processing difficulties became part of the diagnostic criteria for ASD presented in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013). Notwithstanding the recognition of sensory processing difficulties as one of the phenotypical features of ASD, several studies described sensory processing difficulties in other clinical groups as well, for instance in individuals with bipolar disorder, schizophrenia (Brown et al., 2002) or ADHD (Bijlenga et al., 2017). Moreover, sensory processing difficulties are increasingly reported as a separate, independent clinical phenomenon, which has led to the proposed use of an independent sensory processing disorder (SPD) by occupational therapists (Miller et al., 2007), although not part of the leading medical classification systems (e.g. DSM or ICD). It remains largely unknown whether sensory processing difficulties are perhaps not only related to specific psychiatric disorders but also to psychiatric vulnerability in general, i.e. whether these difficulties represent a transdiagnostic phenomenon.

Apart from associations with various psychopathological concepts, sensory processing difficulties have also been associated with various functional problems, also within the general population. For instance, hypersensitivity is correlated with sleeping quality (Engel-Yeger & Shochat, 2012) and pain perception (Engel-Yeger & Dunn, 2011b). Moreover, sensory processing difficulties have been shown to negatively impact well-being, life satisfaction, and quality of life (Costa-López et al., 2021). With regard to internalizing problems, sensory processing is found to be

associated with anxiety level (Engel-Yeger & Dunn, 2011c), negative affect (Engel-Yeger & Dunn, 2011a) and distress (Ben-Avi et al., 2012).

With respect to the association of sensory processing difficulties with more externalizing behaviors, such as aggressive or violent behavior, research in adolescent and adult populations is far more limited. Indeed, previous research did indicate the existence of this association in adolescent and adult populations of individuals with ASD (Gonthier et al., 2016; Mazurek et al., 2013). However, information from other populations – for instance the forensic psychiatric population, known for its high prevalence of aggressive or violent behaviors – is limited to unavailable. Moreover, it remains largely unknown whether and how sensory processing difficulties are related to psychiatric disorders that are associated with externalizing behaviors and that are highly prevalent within forensic psychiatry, such as cluster B personality disorders (Timmerman & Emmelkamp, 2001). The case of Jim, which is exemplary for forensic psychiatric clinical practice, illustrates how investigating this association more thoroughly may be of significant forensic clinical relevance. In sum, the relevance of sensory processing difficulties within the context of externalizing behavior or, more specifically, forensic-psychiatric psychopathology, appears to be a scientifically underexplored but a clinically relevant area of research, as these difficulties are potentially of importance for explaining and treating aggressive behavior.

Aim of this thesis

The research presented in this thesis was conducted to explore the relevance of sensory processing difficulties for (forensic) psychiatric clinical practice, both from a psychopathological and behavioral perspective. Several studies were performed to investigate the association of sensory processing difficulties with psychiatric disorders and with externalizing behavior in adolescent and adult clinical and non-clinical populations. In addition, the thesis contains methodological investigations of clinical instruments developed for the measurement and screening of sensory processing difficulties or externalizing behavior. In line with these main objectives, the following research questions will be answered within this thesis:

- How are sensory processing difficulties associated with psychiatric disorders in adolescent and adult clinical populations?

- Are sensory processing difficulties associated with the symptomatology of perceived stress and occupational burnout in a non-clinical population?
- How representative are the AASP reference data for the general population?
- What is the value of the Dutch self-report Strengths and Difficulties Questionnaire (SDQ) as a screener to predict disruptive behavior in adolescents, including various types of delinquency?.
- Are sensory processing difficulties associated with aggressive behavior in adults with ASD and in adults from a non-clinical population?
- Are sensory processing difficulties associated with substance use in adults with ASD?

Study populations

Analyses presented in this thesis were based on data originating from the following studies. The *Oostwest Project* is an observational study in a population of employees at the Dimence Group Mental Health Care Institutions in the Netherlands. The main aim was to study effects of a changing work situation due to the COVID-19 pandemic, such as the increased working from home and use of telepsychiatry, or social distancing within the work environment. Data were collected between June and August 2020 and are presented in chapters 3 and 7 of this thesis. The *SPAA Study* is an observational study in a population of adults with ASD in treatment at outpatient and inpatient facilities of Dimence Mental Health Care Institution in the Netherlands. The main aim was to study the association of sensory processing difficulties with aggressive behavior in adults with ASD. Data were collected between April 2018 and April 2019 and are presented in chapters 6 and 8. Finally, for chapter 5, data originating from the iBerry Study's baseline measurements were used. The still ongoing iBerry Study is a population-based cohort study designed to investigate the transition from subclinical symptoms to a psychiatric disorder (Grootendorst-van Mil et al., 2021). Baseline data were collected between September 2015 and September 2019.

Outline of this thesis

Part I of this thesis is focused on the association of sensory processing difficulties with psychopathology in general. In chapter 2, I present a meta-analysis of data originating from studies in clinical populations that measured sensory processing difficulties. This study focuses on the overall association with psychopathology, as well as data detailing specific sensory processing patterns per clinical subgroup. I further investigate the association of sensory processing difficulties with stress and burnout symptomatology across the normal population in chapter 3 and the representative quality of the AASP reference data in chapter 4.

Part II of this thesis is focused on the association of sensory processing difficulties with externalizing behavior, in particular with aggression. In chapter 5, I present a methodological analysis of early screening for disruptive behavior among high-risk adolescents. In chapter 6, the association of sensory processing difficulties with aggressive behavior and related subtypes was studied in adults with ASD. I further explore this association in a non-clinical population in chapter 7, in order to investigate whether or not the underlying phenomena are bound to clinical populations. In chapter 8, I explore the association of sensory processing difficulties and substance use – and in particular alcohol use – in adults with ASD.

Chapter 9 provides a general discussion of the main findings and relevant methodological considerations. Additionally, hypotheses about the forensic psychiatric meaning of and mechanisms underlying the reported associations are presented and recommendations for future research are discussed.

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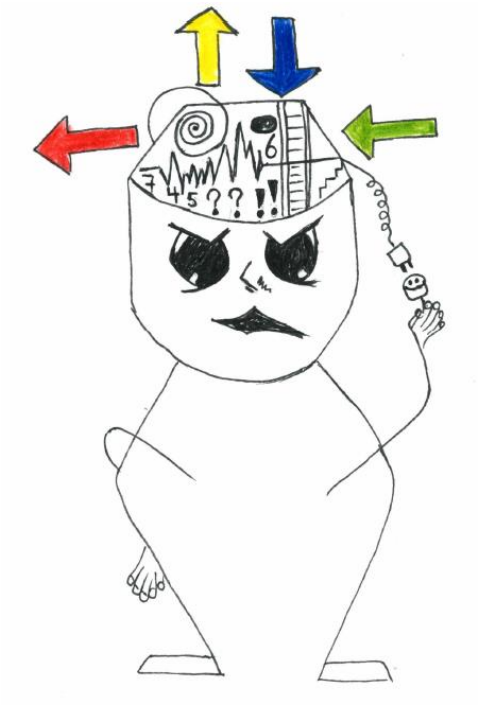
PART I

Sensory processing and psychopathology

CHAPTER TWO

Sensory processing difficulties in psychiatric disorders: a meta-analysis



A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

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.

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

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.

Methods

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.

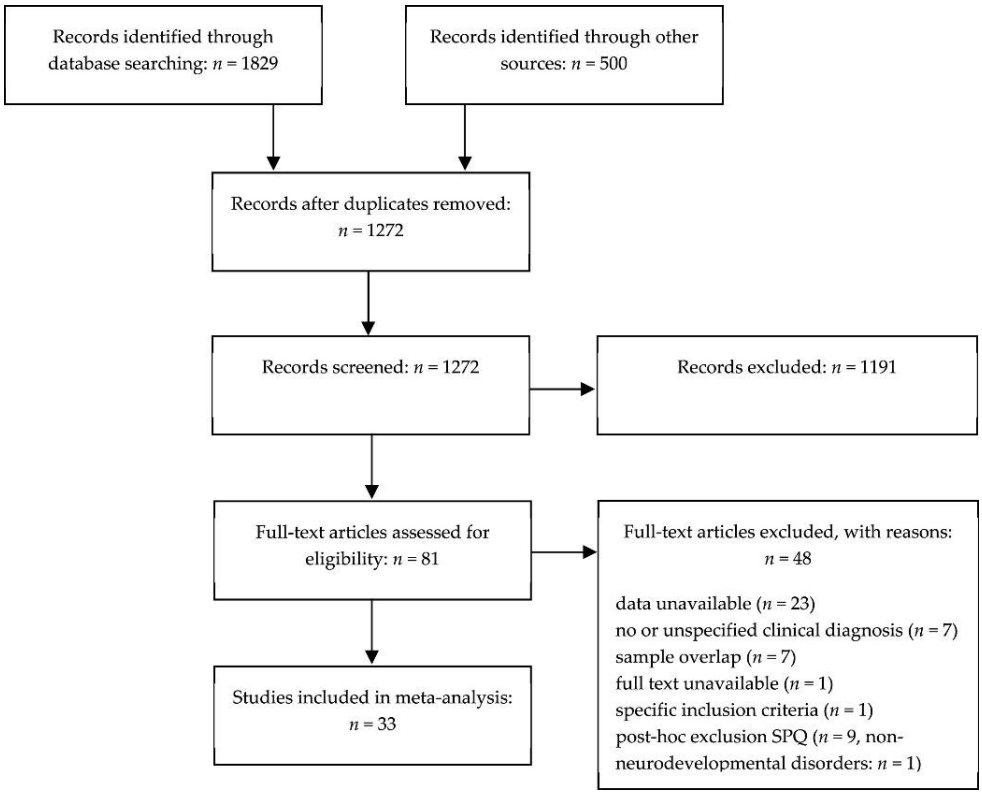
((((AASP OR SPQ OR AADQ) AND (sensor*)) OR ((adult* OR adolesc*) NEAR/3 (sensor*) NEAR/3 (profil*)):ab,ti,kw) OR ((‘sensorimotor integration’/de OR ’mental overstimulation’/de OR ’developmental coordination disorder’/de OR ’visuomotor coordination’/de OR (((sensor* OR visu*-motor* OR visu*-percept* OR 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 Figure 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.

Figure 1

Reference selection process after database search queries.



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.

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. 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

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
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 Jr 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

[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. NR = Not reported.

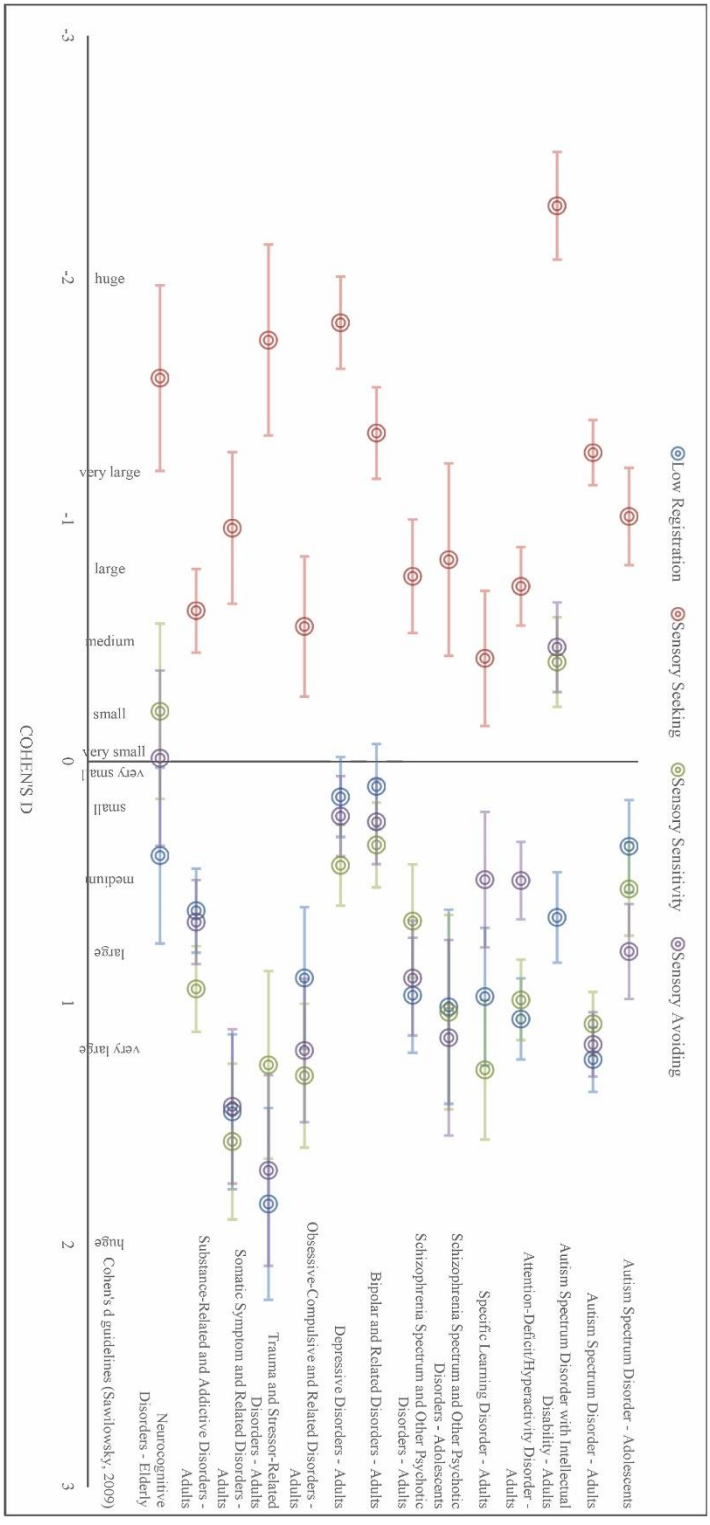
Table 2

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

Clinical diagnosis or diagnosis group	Reference group	Subgroups *K*	Participants *N*	Low Registration *M*	*SD*	*Cohen's d*	Sensory Seeking *M*	*SD*	*Cohen's d*	Sensory Sensitivity *M*	*SD*	*Cohen's d*	Sensory Avoiding *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 leaming 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	
				$t(37) = 1.76$,		$p = .087$	$t(45) = -9.97$,		$p < .001$	$t(38) = -.98$,		$p = .331$	$t(45) = -0.81$,		$p = .936$

Figure 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.reference group data.



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 Figure 2. In general, the majority of the effect sizes were large to very large.

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

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CHAPTER THREE

Sensory processing, perceived stress and burnout symptoms in a working population during the COVID-19 crisis

A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

Abstract

Although previous research suggests an association between sensory processing and perceived stress in a broad spectrum of mental health conditions, it remains unclear whether this phenomenon occurs independently from psychopathology. The present study investigated the association between sensory processing patterns, perceived stress and occupational burnout as a stress-related condition in a working population. We focused on different aspects of sensory processing and used the momentum of a particularly stressful period: during the first months of the global COVID-19 crisis. A total of 116 workers at a mental healthcare institution in The Netherlands completed the Adolescent/Adult Sensory Profile (AASP), the Perceived Stress Scale (PSS-10) and the Burnout Assessment Tool (BAT). Our results demonstrated that higher scores on sensory sensitivity and low registration were associated with higher scores on perceived stress and core burnout symptoms. Sensory hypersensitivity was also associated with more secondary burnout symptoms. Associations were not driven by underlying sensory-related disorders (e.g., ASD or ADHD). In conclusion, sensory processing difficulties are relevant predictors of stress and occupational burnout, also in healthy employees. This phenomenon warrants further attention, as relatively simple adjustments in working environment may possess important preventive effects.

Introduction

Sensory processing is defined as receiving, modulating, integrating and organizing sensory stimuli, and the behavioral response to these stimuli (Miller & Lane, 2000). Within the work environment, this includes the processing of auditory and visual information and other sensory stimuli, underlining the relevance of, for instance, acoustics and lighting. Persons with sensory processing difficulties might miss sound input such as ringing phones or incoming persons, may show humming or whistling in their working environment, or may overreact to colleagues or clients who get to close, etc. In general, humans are neurobiologically programmed to adapt their responses to environmental stimuli, however, variability among the general population is high and some people seem to have more sensitive brains or more difficulties in adapting their behavior to stimuli from their environment. Profound difficulties in sensory processing can be part of several mental health conditions, or may be recognized as a distinct sensory processing disorder (SPD; Miller et al., 2007). Whereas most individuals present a variation in their sensory processing patterns, difficulties in sensory processing might predispose health implications and the development of psychopathology (Brown et al., 2020). Neurodevelopmental disorders such as autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) are often associated with sensory processing difficulties — even leading to incorporation of hyper- and hyporeactivity to sensory stimuli in the diagnostic criteria of ASD (DSM-5; American Psychiatric Association, 2013). Difficulties in sensory processing are, however, not restricted to individuals with neurodevelopmental disorders, and may be recognized as part of a more transdiagnostic phenomenon.

Sensory processing difficulties have been associated in the healthy population also, with various functional problems. On an emotional level, sensory processing is associated with anxiety level (Engel-Yeger & Dunn, 2011c), negative affect (Engel-Yeger & Dunn, 2011a) and distress (Ben-Avi et al., 2012). Moreover, hypersensitivity is positively correlated with sleeping quality (Engel-Yeger & Shochat, 2012) and pain perception (Engel-Yeger & Dunn, 2011b). Sensory processing difficulties have been shown to negatively impact well-being, life satisfaction, and quality of life (Costa-López et al., 2021). As such, sensory processing difficulties may interfere with performance and participation in different life contexts, including work. Furthermore, it may well be that sensory processing

difficulties drive exaggerated stress responses to environmental stimuli, including work stress.

The possible association between sensory processing and perceived stress has been investigated primarily within the context of psychopathology and, particularly, in neurodevelopmental disorders. In children with ASD, sensory processing is associated with either heightened or lower stress hormone (cortisol) levels, depending on the type of aspect of sensory processing (Corbett et al., 2009). Hypersensitivity for sensory stimuli, for example, was associated with higher cortisol levels and higher physiological arousal during play activities (Corbett et al., 2016). In children with ADHD, sensory sensitivity was found to moderate the activity of the hypothalamic–pituitary–adrenal (HPA) axis and to differentiate between subtypes of ADHD (Reynolds et al., 2010). There are also indications that sensory sensitivity is a relevant factor for perceived stress and anxiety in individuals with autistic traits, i.e., also in individuals without a clinical disorder. Whether sensory sensitivity leads to exaggerated stress responses, or exaggerated stress responses leads to sensory sensitivity, is largely unknown (Amos et al., 2019). In veterans with acquired exaggerated stress responses due to PTSD, light and noise sensitivity are associated with more avoidance, intrusive experiences and hyperarousal (Callahan & Storzbach, 2019). Also in children, various aspects of sensory processing are found to be associated with posttraumatic stress (Yochman & Pat-Horenczyk, 2020). Although results from previous research suggest an association between sensory sensitivity and perceived stress in psychopathology, it remains unclear whether sensory processing patterns other than sensory sensitivity, such as sensory seeking or sensory avoiding behaviors or those registered as sensory stimuli (Brown et al., 2001), are relevant in this context, and whether this phenomenon occurs independently from psychopathology.

A well-known stress-related condition is occupational burnout. In short, this condition can be defined as exhaustion due to prolonged exposure to work-related problems (Canu et al., 2021). Although exhaustion is indeed at the symptomatologic core of occupational burnout, Schaufeli and colleagues (2020) broadened this definition by including other core and additional dimensions: "a work-related state of exhaustion that occurs among employees, which is characterized by extreme tiredness, reduced ability to regulate cognitive and emotional processes, and mental distancing. These four core dimensions of burnout are accompanied by depressed mood as well as by non-specific psychological and psychosomatic complaints".

Whether sensory processing difficulties may serve as precursors or markers for occupational burnout, is largely unknown. Some studies described an association of sensory processing sensitivity with burnout (Meyerson et al., 2020; Pérez-Chacón et al., 2021). However, these studies measured the concept of 'sensory processing sensitivity', which represents a proposed personality trait characterized by deeper cognitive processing of stimuli and heightened emotional reactivity, and is conceptually different from (or even unrelated to) the more neurological approach of sense-based processing and related sensory processing disorders (SPD; Aron et al., 2012). In other words, 'being a hypersensitive person' is not the same as 'having sensory processing difficulties', and the other way around. As yet, it is unknown if and how these sensory processing difficulties are part of occupational burnout symptomatology or sequelae.

Sensory processing difficulties can be transient over time and can be measured in detail for each sensory modality separately by fundamentally determining the individual neurological threshold (the intensity of sensory stimulation needed to evoke neural response) and the resulting behavioral response to the incoming sensory information (Dunn, 1997), without directly taking personality traits, emotional reactivity and depth of cognitive processing into account. In the present study, we focused on this neurological approach, and studied the associations of these detailed modal sensory patterns to the complex symptomatology of perceived (job) stress and occupational burnout. We studied these associations in a (predominantly healthy) working population, however, during the stressful first months of the global COVID-19 crisis, which increased the statistical power to find a meaningful effect on occupational burnout. We hypothesized that the COVID-19 crisis would serve as a general risk factor for burnout, not only in 'front line' health care professionals, but also in other workers, due to higher job demands and lower job positives. Many workers were facing work overload, restricted work environment, and challenges to come up with effective strategies to continue their jobs. At the same time, they were facing lower job positives like enriching social interaction with colleagues and building competence.

Methods

The Oostwest Project is an observational study in a population of employees at the Dimence Group Mental Health Care Institutions in The Netherlands. The main aim was to study the effects of a changing work situation due to the COVID-19 pandemic, such as the increased working from home and use of telepsychiatry, or social distancing within the work environment. Data were collected between June and August 2020. The project was approved by the institutional review board of Dimence Group (CWO-062020PSFB). All participants provided written informed consent after procedures were fully explained, in accordance with the World Medical Association Declaration of Helsinki. The survey was distributed to each participant using the GemsTracker online survey system. A total of 251 employees received our study information sheet and were invited to participate. After sufficient reflection time, 116 employees (M_{Age} = 44.7, SD_{Age} = 12.2; N_{Male}/N_{Female} = 33/83) agreed to participate in the study. In total, five participants did not complete all four parts of the survey. However, all 116 participants did complete the first part of the survey, including the Work Situation questionnaire as described below.

The Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002; Brown et al., 2001; Rietman, 2007), a 60-item self-report questionnaire, was used to measure responsiveness to various sensory stimuli and to identify sensory processing difficulties that may hinder daily functioning. The AASP is the most frequently used instrument model for this purpose in adults and adolescents with ASD, however is also suited for use in other populations (DuBois et al., 2017). The questionnaire produces four continuous subscale scores ranging from 15 to 75, representing the four quadrants of the Model of Sensory Processing (Brown et al., 2001; Dunn, 1997): low registration (i.e., under-registration, e.g., missing stimuli such as sound input or slowed responses), sensory seeking, sensory sensitivity, and sensory avoiding. Each subscale consists of 15 items, rated on a 5-point Likert scale from never (1) to always (5). The values of the alpha coefficients for the quadrant scores range between 0.64 to 0.78 (Pearson Education, 2008), which indicates satisfactory internal consistency. Within the present sample, the calculated Cronbach's alpha was 0.84. We used all four raw quadrant scores for our analyses. Additionally, we calculated an AASP sum score, with a range of 60 to 300. For descriptive purposes, we calculated reference scores based on the data published in the instrument's manual (Brown & Dunn, 2002).

The 10-item version of the Perceived Stress Scale (PSS-10; Cohen et al., 1994) was used to measure the degree to which individuals appraise daily life situations in the last month as stressful and consists of items measuring self-efficacy and helplessness. This short version of the PSS has demonstrated high validity and reliability (Cohen, 1988; Cohen et al., 1983). Each item is answered on a Likert scale from 'never' (0) to 'very often' (4). The total score ranged from 0 to 40, with a higher score indicating greater stress. The perceived helplessness subscale (ranging from 0 to 24) and the perceived self-efficacy subscale (ranging from 0 to 16) have been calculated as well. The calculated continuous raw scores were used in our statistical analyses, as described below. For descriptive purposes, the raw scores were compared to the reference data for males and females, as described in the PSS-10 manual (Cohen et al., 1994). Within the present sample, the calculated Cronbach's alpha was 0.87.

The Burnout Assessment Tool (BAT) was used to estimate burnout symptomatology (Schaufeli et al., 2019). This 33-item self-report questionnaire consists of six different subscales: exhaustion, mental distance, cognitive impairment, emotional impairment, psychological complaints, and psychosomatic complaints. In line with instructions in the manual, the first four core symptoms were interpreted both separately and combined into a core symptoms score. Additionally, the latter two subscales were interpreted separately and combined as a secondary symptoms score. The core symptoms score, secondary symptoms score and the individual subscale scores were compared to the reference group of Flemish workers, as published in the instrument's manual (Schaufeli et al., 2019). This resulted in 'no risk', 'at risk' and 'very high risk' scores. The instrument demonstrated adequate reliability, as well as convergent and discriminant validity with other burnout measures (Schaufeli et al., 2020). Within the present sample, the calculated Cronbach's alpha was 0.94.

We measured various demographic and work-related variables. The applied educational levels were lower, middle and higher, in line with Dutch governmental guidelines issued by Statistics Netherlands. The lower educational level included primary and special primary education, prevocational education, the first three years of senior general secondary education and pre-university secondary education and the lower secondary vocational training. The middle educational level included the upper secondary education, vocational training and middle

management and specialist education. The higher educational level included the associate, bachelor, master and doctoral degrees. These variables were used for sample characteristics and for limitation of confounding effects. We used a self-assembled 15-item Work Situation questionnaire to measure the perceived changes in work situation since the start of the COVID-19 crisis in The Netherlands, in March 2020. All questions were answered on a 5-point Likert scale, ranging from 'strongly decreased' to 'strongly increased'. Data resulting from this questionnaire were solely used for descriptive purposes.

For all statistical analyses, we used IBM SPSS version 25.0 (IBM Corp., New York, NY, USA). For descriptive purposes, means and standard deviations were calculated for continuous covariates, determinants and outcome variables and frequencies for dichotomous variables. In addition, where available, reference group distributions in percentages were calculated for sensory processing and stress- and burnout-related variables. We used multiple linear regression models to analyze the associations of sensory processing (AASP raw quadrant scores and AASP total score) with stress and burnout as outcome variables (PSS perceived stress, BAT core symptoms and BAT secondary symptoms). Secondary analyses were conducted for the more detailed subscale scores of the PSS and BAT. To overcome multicollinearity problems (high condition index values (> 30) and unstable *b*-coefficients) between the four raw quadrants of sensory processing, we applied forward selection as model building strategy. Age, sex, and educational level were standard covariates in the models. In the regression analyses with PSS total and subscale scores as outcome variable, one influential case was excluded due to random answering of this specific questionnaire. All other applicable statistical assumptions were met. Effect sizes of the predictor variables are expressed in Cohen's f^2 , calculated using the R^2 and ΔR^2 of each model and interpreted according to Cohen's guidelines (Cohen, 2013).

Results

General sample characteristics are presented in Table 1. The majority of participants were female. Most participants were higher educated. A small number of participants reported potentially sensory-related conditions, such as a diagnosis of

ASD, ADHD, neurological disease or the use of drugs or medications with possible sensory related effects in the last 30 days.

Perceived changes in work situation since the start of strict measures of social distancing, quarantine and lockdown in The Netherlands due to the COVID-19 pandemic in March 2020 are presented in Figure 1. Most of the participants in our sample experienced an increased level of workload. Moreover, a substantial part of the sample reported increased work-life conflicts and decreased effectiveness. Factors related to interaction with others partly showed decreased levels, although several employees (mainly working in inpatient settings) reported more involvement, feedback, social support, and appreciation by others. Approximately one third of our sample reported experiencing less pleasure in work, although job and financial security were perceived as fairly unchanged. Aggression-related

Table 1

General sample characteristics (n = 116).

Descriptive		**%**
Age (*M*, *SD*)		44.7 (12.2)
Sex	Female	71.6
	Male	28.4
Educational level	Lower [A]	3.4
	Middle [B]	22.4
	Higher [C]	74.1
Partner		86.2
Children		70.7
Profession	Psychologist/Psychiatrist	20.7
	Social Worker	18.1
	Nurse	12.9
	Other Clinical	6.0
	Security	6.9
	Consultancy and Management	24.1
	Secretarial and Administrative	11.2
Medical [D]	ASD [E]	2.6
	ADHD [F]	4.3
	Drugs or medication in last 30 days [G]	6.9
	Neurological diseases	4.3

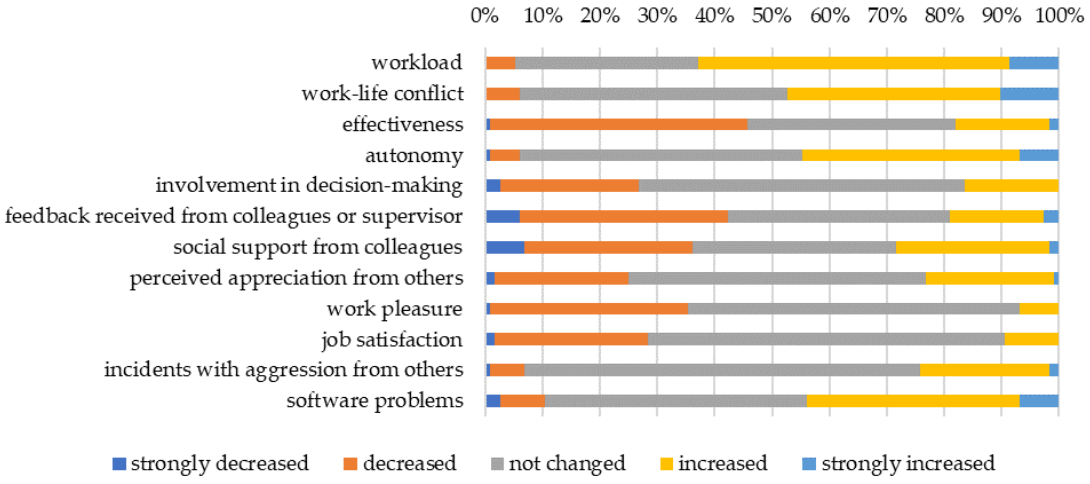
[A] Primary and special primary education, prevocational education, first three years of senior general secondary education and pre-university secondary education, lower secondary vocational training; [B] Upper secondary education, vocational training, middle management and specialist education; [C] Associate degree, bachelor degree, master degree, doctoral degree; [D] Variables known to be associated with sensory processing; [E] ASD = autism spectrum disorder; [F] ADHD = attention-deficit/hyperactivity disorder; [G] Drugs, which may influence sensory processing (e.g., antipsychotics, antidepressants, nausea medication or recreational drugs).

incidents were reported as increased by a minority in the sample, mainly in the clinical setting. Finally, an increase in software problems was reported by almost half of the participants.

Means and standard deviations of all main measurements are presented in Table 2. In general, compared to the reference group of the AASP, our group of (predominantly healthy) workers was more often on the higher extremes of sensory sensitivity and sensory avoiding than expected. That means, more mental health professionals than expected reported to be hypersensitive to sensory stimuli and more mental health professionals than expected reported to avoid sensory

Figure 1

Perceived degree of changes in work situation since the Dutch COVID-19 measures of March 2020.



stimulation. For perceived stress however, more participants in our sample than expected reported low stress (31% vs. 15%) and fewer participants than expected reported high stress (8% vs. 15%). On the burn-out scale, between 4.5% and 17.1% of participants in our sample reported the various (core or secondary) symptoms that indicate increased risk for burnout.

Table 2

Means and standard deviations of all involved total and subscale scores.

Instrument	Score	*M* (*SD*)	Comparison with Reference Group Data (%)				
AASP [B]			––	–	=	+	++
	Low registration	29.4 (6.0)	3.8	11.3	67.0	17.0	0.9
	Sensory seeking	50.1 (6.6)	2.7	10.0	70.0	17.3	0.0
	Sensory sensitivity	35.2 (8.2)	0.0	12.4	66.7	13.3	7.6
	Sensory avoiding	36.34 (8.5)	1.9	7.5	67.3	15.0	8.4
	Total score	150.9 (19.5)	[A]	[A]	[A]	[A]	[A]
PSS				<–1 SD	=		>+1 SD
	Perceived self-efficacy	11.6 (2.4)		[A]	[A]		[A]
	Perceived helplessness	6.1 (4.1)		[A]	[A]		[A]
	Perceived stress	10.5 (5.7)		30.6	61.3		8.1
BAT				Low risk	At risk		Very high risk
	Exhaustion	2.0 (0.6)		95.5	1.8		2.7
	Mental distancing	1.6 (0.5)		92.8	6.3		0.9
	Cognitive impairment	1.9 (0.5)		94.6	3.6		1.8
	Emotional impairment	1.7 (0.5)		82.9	13.5		3.6
	Core symptoms	1.8 (0.4)		94.6	4.5		0.9
	Psychological complaints	2.1 (0.6)		[A]	[A]		[A]
	Psychosomatic complaints	1.9 (0.7)		[A]	[A]		[A]
	Secondary symptoms	2.0 (0.6)		88.3	9.9		1.8

[A] No reference group data available; [B] AASP reference values range from –– 'much less than most people' to ++ 'much more than most people'.

Results of our primary multiple regression analyses are presented in Table 3. In general, sensory processing problems were associated with higher levels of perceived stress, with more core burnout symptoms and with more secondary burnout symptoms, with medium to large effect sizes. Individuals with higher scores on low registration (having problems to notice or detect changes in sensory situations) and on sensory sensitivity (having problems of hypersensitivity),

perceived more stress and reported more burnout symptoms. Table 4 shows that sensory processing problems were associated with all stress- and burnout-related subscale scores separately. Largest effect sizes were seen for psychological and psychosomatic complaints and exhaustion in relation to sensory sensitivity and low registration.

As a post-hoc sensitivity analysis, the primary multiple regression analyses, as presented in Table 3, were repeated after exclusion of individuals with known medical conditions that are related to sensory problems (ASD, ADHD, neurological disease, or drug/medication use; $n = 15$), see Table 5. In the population without these medical conditions, we still found that low registration was related to perceived stress and core symptoms of burnout, and that hypersensitivity was related to secondary symptoms of burnout. Overall, associations remained statistically significant, although effect sizes were smaller.

Table 3

Multiple regression models with AASP raw quadrant and total scores, and stress- and burnout-related total scores.

	Perceived Stress	Core Burnout Symptoms	Secondary Burnout Symptoms
Low Registration	$b = 0.262$ [0.071, 0.453], $p = 0.008$	$b = 0.025$ [0.010, 0.040], $p = 0.001$	[A]
Sensory Seeking	[A]	[A]	[A]
Sensory Sensitivity	$b = 0.156$ [0.013, 0.300], $p = 0.033$	$b = 0.012$ [0.001, 0.023], $p = 0.038$	$b = 0.041$ [0.028, 0.053], $p < 0.001$
Sensory Avoiding	[A]	[A]	[A]
Effect Size [B]	$f^2 = 0.26$	$f^2 = 0.33$	$f^2 = 0.41$
AASP Total Score	$b = 0.123$ [0.071, 0.174], $p < 0.001$	$b = 0.010$ [0.006, 0.015], $p < 0.001$	$b = 0.018$ [0.013, 0.023], $p < 0.001$
Effect Size [B]	$f^2 = 0.23$	$f^2 = 0.26$	$f^2 = 0.48$

Note. All regression models were adjusted for covariates sex, age and educational level. [A] Variable excluded from analysis after application of the forward selection method. [B] Effect size of ΔR^2 after adding predictor variable(s) in the second block in comparison to the covariates in the first block.

Table 4

Multiple regression models with AASP raw quadrant and total scores, and stress- and burnout-related subscale scores.

	Perceived Self-efficacy	Perceived Helplessness	Exhaustion	Mental Distancing	Cognitive Impairment	Emotional Impairment	Psychological Complaints	Psychosomatic Complaints
Low Registration	[A]	$b = 0.260$ [0.140, 0.380] $p < 0.001$	$b = 0.025$ [0.006, 0.043] $p = 0.010$	[A]	$b = 0.039$ [0.024, 0.054] $p < 0.001$	$b = 0.029$ [0.014, 0.045] $p < 0.001$	$b = 0.023$ [0.002, 0.045] $p = 0.034$	[A]
Sensory Seeking	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Sensory Sensitivity	$b = -0.095$ [−0.143, −0.047] $p < 0.001$	[A]	$b = 0.022$ [0.008, 0.036] $p = 0.002$	$b = 0.015$ [0.002, 0.027] $p = 0.020$	[A]	[A]	$b = 0.026$ [0.010, 0.042] $p = 0.002$	$b = 0.046$ [0.032, 0.060] $p < 0.001$
Sensory Avoiding	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Effect Size [B]	$f^2 = 0.16$	$f^2 = 0.19$	$f^2 = 0.37$	$f^2 = 0.06$	$f^2 = 0.27$	$f^2 = 0.14$	$f^2 = 0.32$	$f^2 = 0.42$
AASP Total Score	$b = -0.037$ [−0.058, −0.017] $p < 0.001$	$b = 0.085$ [0.047, 0.123] $p < 0.001$	$b = 0.014$ [0.009, 0.019] $p < 0.001$	$b = 0.006$ [0.001, 0.012] $p = 0.014$	$b = 0.012$ [0.007, 0.016] $p < 0.001$	$b = 0.007$ [0.002, 0.012] $p = 0.005$	$b = 0.017$ [0.011, 0.023] $p < 0.001$	$b = 0.019$ [0.013, 0.025] $p < 0.001$
Effect Size [B]	$f^2 = 0.13$	$f^2 = 0.20$	$f^2 = 0.28$	$f^2 = 0.06$	$f^2 = 0.23$	$f^2 = 0.08$	$f^2 = 0.36$	$f^2 = 0.41$

Note. All regression models were adjusted for covariates sex, age and educational level. [A] Variable excluded from analysis after application of the forward selection method. [B] Effect size of ΔR^2 after adding predictor variable(s) in the second block in comparison to the covariates in the first block.

Table 5

Multiple regression models with AASP raw quadrant and total scores, and stress- and burnout-related total scores.

	Perceived Stress	Core Symptoms Burnout	Secondary Symptoms Burnout
Low Registration	b = 0.337 [0.152, 0.522], p < 0.001	b = 0.030 [0.016, 0.045], p < 0.001	[A]
Sensory Seeking	[A]	[A]	[A]
Sensory Sensitivity	[A]	[A]	b = 0.036 [0.021, 0.051], p < 0.001
Sensory Avoiding	[A]	[A]	[A]
Effect Size [B]	f^2 = 0.16	f^2 = 0.21	f^2 = 0.26
AASP Total Score	b = 0.109 [0.051, 0.168], p < 0.001	b = 0.009 [0.005, 0.014], p < 0.001	b = 0.016 [0.010, 0.022], p < 0.001
Effect Size [B]	f^2 = 0.16	f^2 = 0.20	f^2 = 0.34

Note. All regression models were adjusted for covariates sex, age and educational level. [A] Variable excluded from analysis after application of the forward selection method. [B] Effect size of ΔR^2 after adding predictor variable(s) in the second block in comparison to the covariates in the first block.

Discussion

In the present study, we explored the association between sensory processing on the one hand and perceived stress and burnout symptomatology on the other hand in a working population during a highly demanding crisis period. Our results indicate that both sensory sensitivity and low registration are relevant in this context. Hypersensitivity for sensory stimuli was associated with more stress, more core symptoms of burnout, such as exhaustion, mental distancing and cognitive and emotional impairment, and more secondary symptoms of burnout, such as psychological and psychosomatic complaints. Under registration of sensory stimuli was associated with more stress and more core symptoms of burnout. Effect sizes of these associations were medium to large. Post hoc sensitivity analysis revealed that correction for medical conditions, such as ASD, ADHD, or medication use, reduced effect sizes, however did not fully explain the found associations. On a more detailed level of stress perception, hypersensitivity was associated with lower levels of perceived self-efficacy, whereas under-registration of sensory stimuli were associated with higher levels of perceived helplessness.

Our results are in line with earlier studies on sensory sensitivity and perceived stress (Amos et al., 2019; Callahan & Storzbach, 2019; Corbett et al., 2016; Corbett et al., 2009; Reynolds et al., 2010; Yochman & Pat-Horenczyk, 2020). Whereas previous research was often done in clinical (child) populations of patients with

neurodevelopmental symptomatology, with known medical conditions that influence sensory processing as well as coping with stress, our study shows that sensory processing is also related to perceived stress in healthy workers. Our results add to recent studies that focused on the association of sensory processing sensitivity and occupational burnout (Meyerson et al., 2020; Pérez-Chacón et al., 2021). Risk of burnout is not only heightened by the more static vulnerability of personality traits such as 'hypersensitive persons', but is probably also increased in individuals with neurodevelopmental difficulties in sensory processing. Next, sensory processing difficulties could be considered as a potential part of burnout symptomatology or sequelae.

Although our study design limits causal inference, the more detailed measurement of sensory processing, stress and burnout enables us to cautiously explore hypothetical causal explanations. Largest effect sizes were seen in the associations of sensory sensitivity with psychological and psychosomatic complaints of occupational burnout. To some extent, these concepts might show overlap. It is tempting to speculate that psychosomatic complaints are related to interoception, the perception of bodily sensations, which is not assessed in the AASP questionnaire. Previous research suggests that the altered interoception may result from acute or chronic stress (Schulz & Vogele, 2015). This (over) awareness of internal stimuli as a result of perceived stress might also apply to the other, more externally directed senses. This activation of all senses in reaction to stress seems evolutionary intuitive. On an item level, psychological complaints of burnout are operationalized by sleeping problems, anxiety, and problems with crowdedness and noise. Clearly, this last item might have conceptual overlap with sensory sensitivity to auditory stimuli. However, in addition to the suggested conceptual overlap, sensory processing difficulties could also be a transdiagnostic factor in relation to psychological complaints. In particular, experiencing heightened levels of sensory sensitivity resulting from chronic stress could eventually be exhausting and, thus, cause sleeping problems. Finally, under registration of external stimuli—low registration—could well be related to or perhaps result from problems with concentration and attention as signs of burnout-related cognitive impairment. More research is needed to unravel the exact underlying causal mechanisms in place.

The Oostwest Project data collection started in June and was completed in August 2020. These summer months cover the tail of the 'first wave' of coronavirus

infections and government measures in The Netherlands, including social distancing, the closing of schools and childcare centers, cafes and restaurants, and sport clubs, and the urgent advice to work from home. As a result, some employees in the study sample were advised or obliged to work from home, while others could continue their clinical work in institutions with in-patient populations suffering severe mental illness, which could be exaggerated by the presence of the stressful psychosocial factor amid COVID-19. For many out-patient mental healthcare workers, it resulted in increased application of telepsychiatry, a worldwide phenomenon (Shore et al., 2020). Our population reported increased problems on various aspects related to the individual work situation in this challenging, demanding, and downright tough period for caregivers and other employees. These circumstances could have resulted in more variance on stress- and burnout-related variables, whereas social distancing overall might decrease levels of sensory stimulation. Although we did not observe high numbers of employees facing occupational burnout during our measurement, it is possible that many continued to have high job demands and low job positives, eventually leading to more burnouts during the following phases of the pandemic.

Whether our results are generalizable to other (working and non-working) populations is largely unknown. Due to the healthy worker effect (McMichael, 1976), morbidity in our source population was assumed to be decreased in comparison with the general population. However, reported sensory-related factors, such as ASD or ADHD, seem to be as prevalent as or even more prevalent in our sample in comparison to the general population. A second limitation is the potential risk for selection bias. Selective non-response could have led to both over- or underestimation of perceived stress and/or burnout symptomatology. It is however unknown whether the found associations with sensory processing difficulties might be different in those non-responded. Third, the risk for information bias cannot be ruled out, as we used self-report measures for both determinants and outcomes. Finally, we assume the inclusion of covariates and the executed sensitivity analyses have addressed potential confounding effects, however residual confounding can never be ruled out.

Our study underscores the relevance of sensory processing in general and specific sensory processing patterns in perceived stress, occupational burnout and potentially a broad spectrum of mental health conditions (Brown et al., 2020). Problems in sensory processing are highly related to psychological and

psychosomatic burnout complaints, which indicates that sensory processing, particularly hypersensitivity, is a transdiagnostic factor for psychopathology. More research is needed to thoroughly investigate the specific role of sensory processing in mental health. From a more clinical or occupational point of view, our results suggest a bidirectional approach. First, for employees who experience sensory processing difficulties, it is important to be aware of stress- and burnout-related problems. Second, employers do well to create a healthy working environment by paying attention to sensory processing patterns and difficulties in their employees and, as a result, regulate the levels of input on all senses. Employers can offer awareness on the subject, as well as personal (e.g., occupational diagnostics and therapeutic interventions) and environmental (e.g., acoustics, smell and lighting within the work space) prevention and support.

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PART II

Sensory processing and externalizing behavior

CHAPTER SIX

Sensory processing and aggressive behavior in adults with autism spectrum disorder

A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

Abstract

Autism spectrum disorder (ASD) may be accompanied by aggressive behavior and is associated with sensory processing difficulties. The present study aims to investigate the direct association between sensory processing and aggressive behavior in adults with ASD. A total of 101 Dutch adult participants with ASD, treated in outpatient or inpatient facilities, completed the Adolescent/Adult Sensory Profile (AASP), the Reactive-Proactive Aggression Questionnaire (RPQ), and the Aggression Questionnaire—Short Form (AQ-SF). Results revealed that sensory processing difficulties are associated with more aggressive behavior ($f^2 = 0.25$), more proactive ($f^2 = 0.19$) and reactive aggression ($f^2 = 0.27$), more physical ($f^2 = 0.08$) and verbal aggression ($f^2 = 0.13$), and more anger ($f^2 = 0.20$) and hostility ($f^2 = 0.12$). Evidence was found for an interaction of the neurological threshold and behavioral response on total aggression and hostility. Participants with higher scores in comparison to the norm group in sensory sensitivity had the highest risk of aggressive behavior. In conclusion, clinical practice may benefit from applying detailed diagnostics on sensory processing difficulties when treating aggressive behavior in adults with ASD.

Introduction

Adults with autism spectrum disorder (ASD) are often confronted with problems in social, professional, and educational functioning and in physical and mental health (Howlin & Moss, 2012). In children with ASD, aggression is associated with more negative outcomes, such as decreased quality of life or less educational and social support (Fitzpatrick et al., 2016). More than half of all children with ASD demonstrate aggressive behavior directed at a caregiver or physical aggression in various situations (Kanne & Mazurek, 2011; Mazurek et al., 2013). When compared with typically developing children, aggressive behavior seems more common in children with ASD (Mayes et al., 2012). Compared with children with other intellectual and neurodevelopmental disorders, children with ASD showed more physical and reactive aggression (Farmer & Aman, 2011). In adults with ASD, there is no clear evidence for increased risk for aggressive or violent behavior (Im, 2016). However, on the level of an individual person with ASD, violent behavior could result from (undetected or untreated) third variables, e.g., family environment, criminality, psychiatric comorbidity (Del Pozzo et al., 2018), or various factors associated with ASD, such as younger age, repetitive behaviors, or sensory difficulties (Im, 2016). Research on factors that are associated with aggressive behavior in individuals with ASD might help inform treatment strategies, as too little is known about the underlying constructs or mechanisms to understand the association between ASD and aggression.

Specific phenotypic features, such as difficulties in sensory processing, may play an important role in the manifestation of aggression. Sensory processing difficulties are strongly associated with ASD and, from a more clinical point of view, considered to be part of ASD symptomatology. Sensory difficulties have therefore been added to the diagnostic criteria for ASD in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM–5; American Psychiatric Association, 2013). In general, sensory processing in persons with ASD differs from that in persons in the general population (Kern et al., 2006). Sensory difficulties are present in the vast majority of children with ASD (Leekam et al., 2007), and differences in comparison with children without ASD are seen on the full range of sensory processing issues (Tomchek & Dunn, 2007). Differences are largest for sensory under-responsivity, followed by sensory over-responsivity and sensory seeking (Ben-Sasson et al., 2009). Sensory difficulties in patients with ASD seem to persist through lifetime (Leekam et al., 2007). In adults with ASD, sensory differences were

present in 94 percent of the population, although there is considerable diversity across individuals with ASD (Crane et al., 2009). Sensory over-responsivity is particularly more common in adults with ASD in comparison to adults without ASD, and the severity of sensory over-responsivity is positively correlated with the level of autistic symptoms (Tavassoli et al., 2014).

Sensory difficulties are a plausible, relevant phenomenon in the context of aggressive or violent behavior in persons with ASD. Mazurek et al. (2013) found first indications of a positive association between sensory processing issues and aggressive behavior in children and adolescents with ASD. Gonthier et al. (2016) reported a small positive correlation between sensation-seeking behavior and aggression directed towards others in a sample of adults with ASD and comorbid profound to severe intellectual disability.

Several models of sensory processing have been developed. Dunn's Model of Sensory Processing (Brown et al., 2001; Dunn, 1997) is among the most recognized models on this subject. In short, the model combines two continua: the vertical neurological threshold continuum for noticing of or reacting to stimuli, ranging from a low threshold or sensitization to a high threshold or habituation, and the horizontal behavioral response continuum, indicating the response to the neurological thresholds, ranging from responses in accordance with thresholds to responses to counteract the thresholds. The interaction of these continua results in a quadrant matrix: low registration, sensory seeking, sensory sensitivity, and sensory avoiding (Dunn, 1997). As a result, sensory processing issues are conceptualized, and measured, in several separate but interdependent factors.

Although aggressive behavior is often analyzed on an aggregated level, aggression is a broad concept that allows specification and differentiation in various ways. An often-used differentiation discriminates between reactive and proactive aggression. Reactive aggression is an angry, impulsive, and defensive reaction to provocation, without thought of personal gain (Crick & Dodge, 1996). It is a response to poor emotion regulation, reduced self-control, diffuse sensory awareness, and heightened impulsivity (Atkins et al., 1993). Proactive aggression refers to instrumental, organized, and "cold-blooded" aggression, which is controlled by external reinforcements and is mostly not anger driven (Raine et al., 2006). In the context of sensory processing, one might hypothesize that higher levels of sensory seeking behavior are associated with proactive aggression, whereas higher levels of

sensory sensitivity or sensory avoiding behavior are associated with reactive aggression. When analyzing aggressive behavior in persons with ASD, we therefore distinguish between reactive and proactive aggression in the context of sensory processing issues. Our study aims to investigate the association between sensory processing difficulties and aggressive behavior in adults with autism spectrum disorder, using differentiated measurements of both sensory processing and aggressive behavior. To the best of our knowledge, this is the first study in which this association is investigated while applying important differentiations in the measurement of both concepts. Clinical practice may benefit from the acquired knowledge on the association between sensory processing difficulties and aggressive behavior in adults with ASD.

Methods

The Sensory Processing and Aggressive Behavior in Autism Spectrum Disorders (SPAA) study is an observational study in a clinical population. Data were collected between April 2018 and April 2019 in outpatient and inpatient populations at units specializing in neurodevelopmental disorders at the Dimence Mental Health Care Institution in the Netherlands. Dimence is a general provider of mental health care for individuals with normal to high IQ (>70). At Dimence, specialized units provide assessment and treatment for adults with ASD. In general, inpatients are characterized by a lower level of functioning compared to outpatients.

Adult patients in treatment at the outpatient or inpatient facilities of Dimence for clinically diagnosed ASD who were willing to provide informed consent were eligible for participation in the study. The local protocol for the assessment of ASD in adults follows the national guidelines for ASD in adults (Kan et al., 2013). The assessment is based on extensive diagnostic interviews by experienced clinicians. These interviews consist of a clinical interview with the individual, a detailed developmental history with a parent or other informant, and an interview on current functioning with someone who is well acquainted with the individual. Semi-structured clinical interviews based on the Autism Diagnostic Interview—Revised (ADI-R; Lord et al., 1994), a *DSM–5* checklist, and all available information from schools and child psychiatric services concerning childhood development are all important parts of the clinical procedure. The predefined exclusion criteria were insufficient knowledge of the Dutch language or other incapacities (e.g., due to

psychosis, drug or alcohol intoxication, or intellectual disability) to understand the provided information.

All therapists at the institution were extensively informed about the study and requested to select potential participants from their individual caseloads by applying the inclusion and exclusion criteria. Next, all selected patients were provided with the study's information sheet by their own therapist. After sufficient reflection time, the patients were asked to consider participating in the study and, if they agreed, to fill out the informed consent form. Patients who provided informed consent were contacted by a research employee to schedule an appointment for completing the survey. During the appointment, a research employee was available at all times to provide brief verbal instructions and to answer questions. All participants were able to complete the survey. Participation was on a voluntary basis, and the participants received no benefit or compensation.

A total of 101 adult patients with a clinical diagnosis of ASD (M_{age} = 32.9, SD_{Age} = 12.4; N_{Male}/N_{Female} = 53/48) were included in the study sample. General sample characteristics are presented in Table 1. The percentage of participating females in our sample (48%) may reflect the increased attention for ASD in females, as well as the focus of Dimence on ASD patients with normal to high IQ (Lai et al., 2011). Females were on average 5.3 years younger than males. The participants admitted to specialized psychiatric hospital units for the treatment of ASD (i.e., inpatients) were on average 5.4 years younger than the participants treated in outpatient facilities, were on average lower educated, and had more often no partner or spouse, and none of them had children. The groups defined by gender and by treatment setting, as presented in Table 1, did not differ with regard to comorbidity. Gender and treatment setting were not associated.

We used the Dutch version of the Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002; Rietman, 2007), a 60-item, self-report questionnaire to obtain information on responsiveness to various sensory stimuli and to identify difficulties in the sensory systems that may hinder an individual in daily functioning. The AASP is the most frequently used instrument model for this purpose in adults and adolescents with ASD (DuBois et al., 2017). The questionnaire produces four continuous subscale scores ranging from 15 to 75, representing the four quadrants of the Model of Sensory Processing (Brown et al., 2001; Dunn, 1997): low registration, sensory seeking, sensory sensitivity, and sensory avoiding. Each subscale consists of

15 items, rated on a 5-point Likert scale from never (1) to always (5). The values of the alpha coefficients for the quadrant scores range from 0.64 to 0.78 (*Technica Report: Adolescent/Adult Sensory Profile,* 2008), which indicates satisfactory internal consistency.

Table 1

General sample characteristics for total sample and by sex and treatment setting.

Descriptive		Total	Males	Females[A]			Outpatient	Inpatient[A]		
		N = 101	N = 53	N = 48			N = 71	N = 30		
Age (M, SD)		32.9	35.4	30.1	t = 2.27 [B]	*	34.5	29.1	t = 2.02	*
		12.4	14.7	8.3			12.8	10.4		
Educational	Lower (%)	34.7	37.7	31.3	U = 1156		23.9	60.0	U = 684	**
level	Middle (%)	49.5	49.1	50.0			57.7	30.0		
	Higher (%)	15.8	13.2	18.8			18.3	10.0		
Paid work (%)		21.8	22.6	20.8	x^2 = 0.05		26.8	10.0	x^2 = 3.48	
Partner (%)		22.8	17.0	29.2	x^2 = 2.13		28.2	10.0	x^2 = 3.96	*
Children (%)		17.8	24.5	10.4	x^2 = 3.43		25.4	0.0	x^2 = 9.26	**
Comorbidity	Depressive/anxiety disorder (%)	36.6	35.8	37.5	x^2 = 0.03		39.4	30.0	x^2 = 0.81	
	ADHD (%)	13.9	15.1	12.5	x^2 = 0.14		14.1	13.3	x^2 = 0.01	
	Other (%)	30.7	30.2	31.3	x^2 = 0.01		29.6	33.3	x^2 = 0.14	

* $p < 0.05$ ** $p < 0.01$

[A] Test of sex and treatment setting: $x^2 = 0.97$, $p = 0.33$.

[B] t-test with equal variances not assumed.

Although the AASP is based on Dunn's Model of Sensory Processing (Brown et al., 2001; Dunn, 1997), the model's two fundamental continua, the neurological threshold and behavioral response continua, are not measured directly but are represented in dichotomized form in the four continuous quadrant scores. For instance, the sensory seeking score consists of items measuring active behavioral responses in situations of lower neurological thresholds. Thus, whereas the model of sensory processing incorporates two dimensions resulting in four categories, the AASP measures these four categories as separate dimensions and, by doing so, transforms the original two dimensions from its underlying model into categories. This introduces several theoretical and methodological problems. In previous research, the quadrant scores were often analyzed separately, without taking the other quadrant scores into account from a theoretical or statistical point of view. However, as all four quadrant scores are based on the same underlying constructs and are therefore theoretically closely related, the quadrant scores would better be interpreted in conjunction with the other three scores. Additionally, application of the original continua would theoretically enable allocation of each individual to one of the quadrants to "type" the most prominent individual's sensory processing pattern.

In line with previous research (Metz et al., 2019), we calculated the neurological threshold and behavioral response continua, each ranging from −120 to 120. Neurological threshold scores were calculated by subtracting the sum of the low neurological threshold quadrant scores from the sum of the high neurological threshold quadrant scores: (low registration + sensory seeking) − (sensory sensitivity + sensory avoiding). To calculate the behavioral response, we subtracted the sum of the passive behavioral response quadrant scores from the sum of the active behavioral response quadrant scores: (sensory seeking + sensory avoiding) − (low registration + sensory sensitivity). Raw quadrant scores were compared to age-related norm groups provided by the instrument's manual and classified as much less than, less than, similar to, more than, or much more than the mean norm score (Brown & Dunn, 2002). According to the data published in the AASP manual, these classifications are based on the norm group mean scores and standard deviations. Likewise, the raw quadrant scores were converted into quadrant norm scores, ranging from −2 to +2. An aggregated-level variable for sensory processing difficulties, the sensory deviation score, was calculated by summing up all four quadrants' norm score deviations from zero, in the range of 0 to 8. Finally, we

calculated an AASP total score, in the range of 60 to 300, by summing up all raw quadrant scores.

The Reactive-Proactive Aggression Questionnaire (RPQ; Raine et al., 2006) is a 23-item, self-report questionnaire for reactive and proactive aggression. All items were measured on a 3-point scale: never (0), sometimes (1), and often (2). The Dutch version of the questionnaire was used (Cima et al., 2013). The instrument contains two subscales: proactive aggression, containing 12 items, and reactive aggression, containing 11 items. Subscale scores were calculated, in the range of 0 to 24 for proactive aggression and 0 to 22 for reactive aggression. The internal consistency of the instrument is good, with Cronbach's alpha scores of 0.86 for the Proactive Aggression and 0.84 for the Reactive Aggression subscales, respectively (Raine et al., 2006). The Dutch version of the RPQ demonstrated good test–retest stability and adequate convergent and discriminant validity (Cima et al., 2013).

The Aggression Questionnaire—Short Form (AQ-SF; Bryant & Smith, 2001) is a short version of the Aggression Questionnaire (Buss & Perry, 1992). It is a 12-item, self-report questionnaire that measures various subtraits of aggression. The Dutch version of the questionnaire (AVL-AV) was used (Hornsveld et al., 2009). The participants rated each item on a 5-point Likert scale, ranging from entirely disagree (1) to entirely agree (5). The questionnaire consists of four subscales: physical aggression, verbal aggression, anger, and hostility. The three item scores per subscale were summated to form a subscale score, with a maximum range of 3 to 15. Next, the four subscale scores were summated to achieve a total aggression score, in the range of 12 to 60. For secondary analyses, we dichotomized the total aggression scores, using the value at +1 standard deviation in our sample as a cut-off. The internal consistency coefficients of the subscales varied between 0.72 and 0.88, which indicates acceptable to good reliability. Adequate validity of the Dutch version of the AQ-SF was demonstrated by correlations with concurrent measurements (Hornsveld et al., 2009).

As covariates, we measured age, gender, country of birth and nationality, marital status, offspring, educational level, and professional status. The therapist was requested, with written permission provided by the participant, to reconfirm the clinical *DSM–5* classification autism spectrum disorder and to provide information about comorbid diagnoses at the time of completing the questionnaire. Finally, we registered each participant as being treated in either outpatient or

inpatient facilities, in which assisted living facilities with permanent supervision were listed as inpatient facilities.

For all statistical analyses, we used SPSS version 25.0 (Corportation, 2017). For subgroup comparisons of sample characteristics, Student's *t*-tests, Mann–Whitney *U* tests, or Pearson's chi-squared tests were applied. To investigate the association of sensory processing and aggressive behavior, multiple linear regression models were used, including gender, age, educational level, and treatment setting as covariates. We added these specific covariates to all regression models to control for potential confounding effects. Previous research indicates that these variables are associated with at least one of the main variables: gender with aggressive behavior (Österman & Björkqvist, 2018), age with sensory processing (Kern et al., 2006), and educational level (a proxy for IQ level) with aggressive behavior (Cooper et al., 2009). Treatment setting reflects the level of functioning and severity of symptoms. As we differentiated seven aggression-related outcome variables, we conducted an equal number of linear regression analyses with AASP raw quadrant scores and covariates as predictors. The more experimental AASP total score, the sensory deviation score, and the combination of neurological threshold and behavioral response were analyzed using additional linear regression analyses.

In line with our expectations, introducing the four raw quadrants scores induced multicollinearity. Table 2 shows Pearson's correlation coefficients between the four AASP raw quadrant scores. In particular, sensory avoiding and sensory sensitivity were highly correlated. The multicollinearity problem was expressed in high condition index values (>30), which also remained high after analyzing model versions with three out of four raw quadrant scores. To solve the multicollinearity problem, we applied forward selection as model building strategy and subsequently, if necessary, backward deletion. Forward selection was not needed in the analyses with the AASP total score and the sensory deviation score and with the neurological threshold and behavioral response scores as independent variables. Effect sizes of the predictor variables are expressed in Cohen's f2 and interpreted according to Cohen's guidelines (Cohen, 2013). We analyzed dichotomized scores for total aggression and sensory processing using Fisher's exact test. The missing data were limited to one missing data point on all of the main variables.

Table 2

Pearson's correlation coefficients between AASP raw quadrant scores.

	Low Registration	Sensory Seeking	Sensory Sensitivity
Sensory Seeking	.26**		
Sensory Sensitivity	.57**	-.07	
Sensory Avoiding	.44**	-.29**	.81**

* $p < .05$ ** $p < .01$

Results

The mean scores and standard deviations for the AASP total, sensory deviation, neurological threshold, behavioral response, and raw quadrant scores are presented in Table 3. Females on average had higher scores than males on the quadrants low registration, sensory avoiding, and sensory sensitivity. Females also had a higher AASP total score and sensory deviation score and lower scores on the neurological threshold and behavioral response. In comparison to inpatients, the outpatient group had higher mean scores on the quadrants sensory avoiding and sensory sensitivity, as well as the AASP total score and the sensory deviation score, and lower scores on the neurological threshold and behavioral response. We found no indication of statically significant differences between males and females on the various aggression scores. Participants treated in outpatient settings showed higher scores on total aggression, reactive aggression, and anger in comparison with inpatients.

The mean sensory deviation score was 4.2, meaning that participants in our sample differed on average 4.2 standard deviations from the norm group on the total of the quadrant scores. In our sample, 97 out of 101 participants showed at least one standard deviation difference from the norm group on the quadrant scores. Half of the participants (51 out of 101) showed at least 5 standard deviations difference, and 4 participants had a maximum sensory deviation score of 8. Standardized quadrant scores are graphically presented in Figure 1. Scores on low registration were in majority 1 or 2 standard deviations higher than the norm group scores. In contrast, the majority of scores on sensory seeking were on minus 1 or minus 2 standard deviations in comparison to the norm group. The majority of scores on both sensory avoiding and sensory sensitivity were 1 or 2 standard deviations higher than the norm group scores.

Table 3

AASP, AQ-SF and RPQ mean scores (standard deviation) for total sample and by sex and treatment setting.

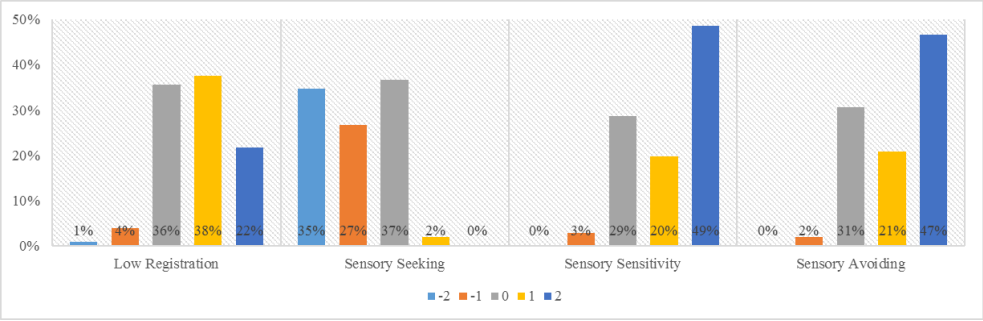
Variable	Total	Males	Females			Outpatient	Inpatient		
Low Registration	38.0 (8.4)	36.0 (8.1)	40.1 (8.3)	$t = -2.50$	*	39.0 (8.0)	35.5 (9.0)	$t = 1.95$	
Sensory Seeking	39.1 (8.8)	40.1 (8.6)	38.1 (8.8)	$t = 1.16$		39.1 (8.2)	39.1 (10.0)	$t = 0.01$ [A]	
Sensory Sensitivity	46.7 (11.3)	42.1 (10.6)	51.7 (9.9)	$t = -4.69$	**	49.0 (10.2)	41.0 (11.9)	$t = 3.43$	**
Sensory Avoiding	47.9 (10.6)	45.0 (10.1)	51.2 (10.3)	$t = -3.07$	**	49.6 (10.2)	43.9 (10.5)	$t = 2.53$	*
AASP Total Score	171.7 (27.2)	163.2 (27.1)	181.0 (24.2)	$t = -3.49$	**	176.8 (24.2)	159 (30.3)	$t = 3.03$	**
Sensory Deviation Score	4.2 (2.2)	3.5 (2.0)	5.0 (2.1)	$t = -3.56$	**	4.5 (2.1)	3.5 (2.1)	$t = 2.26$	*
Neurological Threshold	-17.5 (22.4)	-11.0 (20.3)	-24.7 (22.6)	$t = 3.21$	**	-20.5 (21.9)	-10.4 (22.3)	$t = -2.11$	*
Behavioural Response	2.4 (12.1)	6.9 (10.6)	-2.5 (11.8)	$t = 4.24$	**	.7 (12.3)	6.5 (10.8)	$t = -2.26$	*
Total Aggression	28.0 (9.8)	27.5 (9.1)	28.5 (10.6)	$t = -0.53$		29.4 (9.9)	24.6 (8.7)	$t = 2.31$	*
Reactive Aggression	8.5 (5.1)	7.7 (4.2)	9.4 (5.8)	$t = -1.73$ [A]		9.4 (5.0)	6.5 (4.6)	$t = 2.73$	**
Proactive Aggression	1.5 (1.9)	1.7 (1.8)	1.3 (1.9)	$t = 1.08$		1.6 (1.9)	1.3 (1.8)	$t = 0.83$	
Physical Aggression	5.7 (3.2)	5.8 (3.3)	5.7 (3.2)	$t = 0.19$		6.0 (3.4)	5.2 (2.9)	$t = 1.08$	
Verbal Aggression	6.2 (2.5)	6.0 (2.0)	6.3 (2.9)	$t = -0.62$ [A]		6.3 (2.5)	5.9 (2.6)	$t = 0.61$	
Anger	7.2 (3.7)	6.6 (3.6)	7.8 (3.8)	$t = -1.64$		8.1 (3.6)	5.2 (2.9)	$t = 3.86$	**
Hostility	8.9 (3.6)	9.0 (3.4)	8.7 (3.8)	$t = 0.49$		9.1 (3.7)	8.3 (3.3)	$t = 1.04$	

* $p < .05$ ** $p < .01$

[A] t-test with equal variances not assumed.

Figure 1

Percentage of AASP quadrant scores per distance from the AASP norm group. The labels −2 to 2 are used as equivalent for the AASP's descriptions for norm group comparison, ranging from 'much less than most people' to 'much more than most people'.

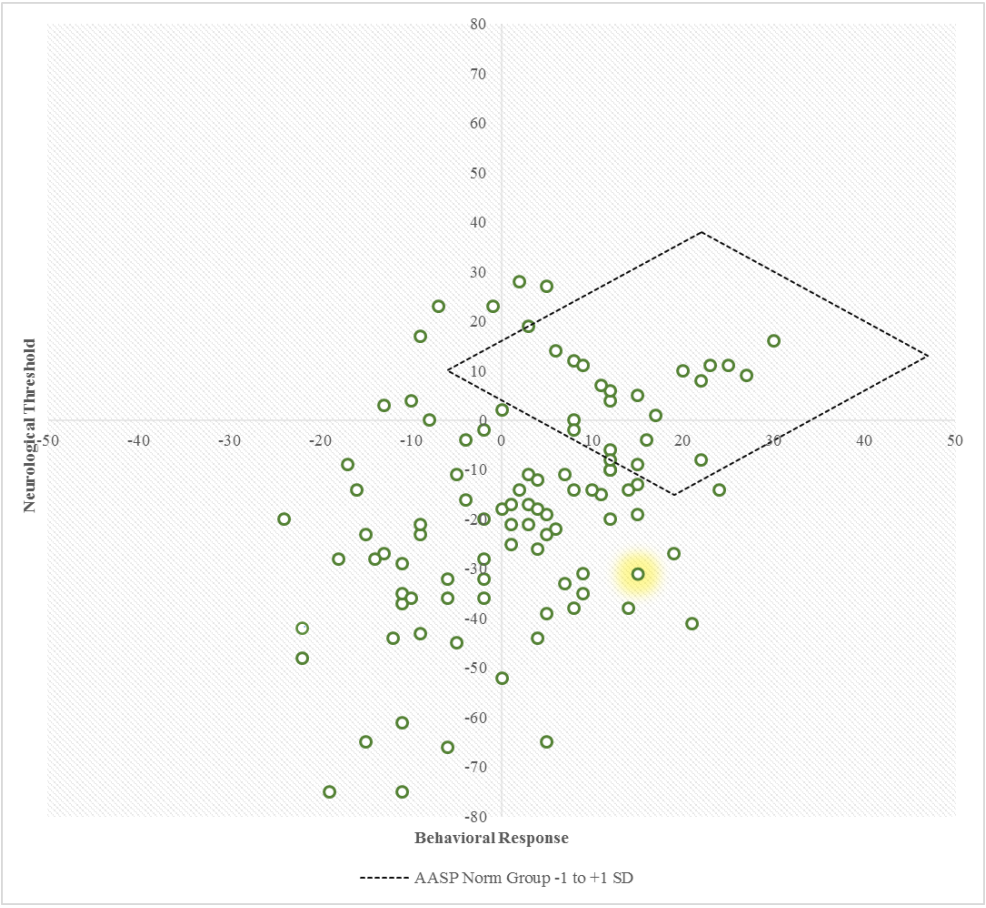


The scatterplot in Figure 2 plots each participant using the calculated neurological threshold and behavioral response scores. The majority of participants had a neurological threshold below zero—thus, at the lower threshold half. The points were fairly evenly distributed over the passive and active sides of the behavioral response axis. The variance in the neurological threshold was larger than the variance in behavioral response. The majority of the participants in our sample tended to have a lower neurological threshold and a more passive behavioral response than the norm group (represented in the diamond shaped region in Figure 2).

Example. Participant Z is a 25-year-old female with ASD, treated in a specialized inpatient facility for adults with ASD. Her AASP quadrant scores were 32 on low registration, 48 on sensory seeking, 56 on sensory sensitivity, and 55 on sensory avoiding. Norm group comparison demonstrated that her scores on low registration and sensory seeking are around the mean norm scores, but her scores on sensory sensitivity and sensory avoiding are much higher than the mean norm group scores. As a result, her sensory deviation score equals 4. The summation of her quadrant scores results in an AASP total score of 191. Using the formula (low registration + sensory seeking) − (sensory sensitivity + sensory avoiding), her neurological threshold is (32 + 48) − (56 + 55) = −31. Using the formula (sensory seeking + sensory avoiding) − (low registration + sensory sensitivity), her behavioral response score equals (48 + 55) − (32 + 56) = 15. The negative (low) neurological threshold score and positive (active) behavioral response score resulted in her representation in the predominantly sensory avoiding quadrant in Figure 2.

Figure 2

Scatterplot based on the calculated neurological threshold and behavioral response scores. The diamond shaped region represents the norm group's neurological threshold scores and behavioral scores, as calculated with the norm group's four quadrant score ranges between −1 and +1 SD. The highlighted data point represents patient Z from the example presented.



Results of the various multiple linear regression analyses are presented in Table 4. For the specific types of aggressive behavior, we found medium to large effects in models with reactive aggression and anger as dependent variables, and scores on sensory sensitivity and sensory seeking as independent variables. Adding low registration and sensory seeking to a model with proactive aggression as dependent variable resulted in a medium effect size. Medium effects were also observed in models with sensory sensitivity associated with verbal aggression and low registration associated with hostility. Sensory avoiding was deleted from all models after applying forward selection.

The AASP total score was positively associated with total aggression score and all specific types of aggressive behavior. Our other measure of general sensory processing difficulties, the sensory deviation score, was also positively associated with total aggression, as well as with verbal aggression, anger, and hostility. Whereas the behavioral response score was statistically significantly associated with total aggression, we found no indication for an association of the neurological threshold with total aggression. However, adding the interaction of neurological threshold with behavioral response scores in the model revealed statistical evidence for effect modification. This means that the behavioral response is associated with aggression in specific ranges of the neurological threshold. On the level of raw quadrant scores, both the sensory sensitivity score and the low registration score were positively associated with total aggression. We identified nineteen participants at the highest risk for demonstrating aggressive behavior (≥1 *SD*). All nineteen participants had elevated scores on sensory sensitivity (≥1 *SD*; $N = 69$; *FET* $p = 0.001$). Fifteen out of the nineteen participants with the highest scores on total aggression had elevated scores on low registration (≥1 *SD*; $N = 60$; *FET* $p = 0.071$).

Table 4

Multiple regression models with AASP raw quadrant, total, sensory deviation, neurological threshold and behavioral response scores and specific types of aggressive behavior.

	Total Aggression	Proactive	Reactive	Physical	Verbal	Anger	Hostility
Low Registration	$b = 0.301$ * (0.049, 0.552)	$b = 0.047$ * (0.001, 0.093)	[A]	$b = 0.106$ ** (0.028, 0.185)	[A]	[A]	$b = 0.142$ ** (0.058, 0.227)
Sensory Seeking	[A]	$b = 0.060$ ** (0.017, 0.102)	$b = 0.179$ ** (0.077, 0.280)	[A]	[A]	$b = 0.079$ * (0.006, 0.152)	[A]
Sensory Sensitivity	$b = 0.272$ * (0.055, 0.488)	[A]	$b = 0.172$ ** (0.078, 0.266)	[A]	$b = 0.089$ ** (0.038, 0.140)	$b = 0.129$ ** (0.062, 0.197)	[A]
Sensory Avoiding	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Effect Size [B]	$f^2 = 0.25$	$f^2 = 0.19$	$f^2 = 0.27$	$f^2 = 0.08$	$f^2 = 0.13$	$f^2 = 0.20$	$f^2 = 0.12$
AASP Total Score	$b = 0.181$ ** (0.109, 0.252)	$b = 0.019$ * (0.004, 0.035)	$b = 0.082$ ** (0.045, 0.119)	$b = 0.035$ ** (0.009, 0.061)	$b = 0.040$ ** (0.021, 0.059)	$b = 0.057$ ** (0.031, 0.083)	$b = 0.048$ ** (0.021, 0.076)
Effect Size [B]	$f^2 = 0.27$	$f^2 = 0.07$	$f^2 = 0.21$	$f^2 = 0.07$	$f^2 = 0.18$	$f^2 = 0.20$	$f^2 = 0.13$
Sensory Deviation Score	$b = 1.611$ ** (0.680, 2.542)	$b = 0.025$ (−0.167, 0.217)	$b = 0.378$ (−0.117, 0.873)	$b = 0.235$ (−0.094, 0.565)	$b = 0.317$ * (0.069, 0.565)	$b = 0.469$ ** (0.133, 0.806)	$b = 0.589$ ** (0.246, 0.932)
Effect Size [B]	$f^2 = 0.12$	-	-	-	$f^2 = 0.07$	$f^2 = 0.08$	$f^2 = 0.12$
Neurological Threshold	$b = -0.006$ (−0.103, 0.090)	$b = 0.022$ * (0.003, 0.040)	$b = 0.008$ (−0.043, 0.058)	$b = 0.016$ (−0.017, 0.049)	$b = -0.016$ (−0.041, 0.010)	$b < 0.001$ (−0.035, 0.034)	$b = -0.006$ (−0.041, 0.029)
Behavioural Response	$b = -0.202$ * (−0.391, −0.013)	$b = -0.013$ (−0.049, 0.024)	$b = -0.039$ (−0.137, 0.059)	$b = -0.049$ (−0.114, 0.015)	$b = -0.001$ (−0.051, 0.049)	$b = -0.062$ (−0.129, 0.006)	$b = -0.090$ * (−0.158, −0.021)
Effect Size [B]	-	-	-	-	-	-	$f^2 = 0.08$
Neurological Threshold * Behavioural Response	$b = -0.010$ ** (−0.017, −0.003)	$b = -0.001$ (−0.002, 0.001)	$b = -0.003$ (−0.007, 0.000)	$b = -0.002$ (−0.004, 0.001)	$b = -0.001$ (−0.003, 0.001)	$b = -0.003$ * (−0.005, < −0.001)	$b = -0.004$ ** (−0.007, −0.002)
Effect Size [B]	$f^2 = 0.15$	-	-	-	-	$f^2 = 0.10$	$f^2 = 0.21$

* $p < .05$ ** $p < .01$

[A] Variable excluded from analysis after application of the forward selection method.

[B] Effect size of ΔR^2 after adding predictor variable(s) in the second block in comparison to the covariates in the first block. Only presented in case of statistically significant ΔR^2.

Discussion

In this study, we found evidence for the association between sensory processing difficulties and aggressive behavior in adults with autism spectrum disorder. Individuals with more sensory processing difficulties showed higher levels of aggressive behavior. In-depth analysis revealed that adults with ASD with higher sensory sensitivity are more likely to show reactive aggression and anger, whereas those with difficulties concerning low registration of sensory input showed more proactive aggression. Adults with ASD who had increased levels of sensory seeking behavior showed both more proactive and reactive aggression, as well as more anger. We found evidence for an interaction between neurological threshold and behavioral response on total aggression and hostility. Finally, we found that the adults with ASD who had higher scores in comparison to the norm group in sensory sensitivity had the highest risk of aggressive behavior.

Our results confirmed findings from previous research with regard to the association of sensory processing difficulties and aggression in children (Bitsika et al., 2017; Mazurek et al., 2013) and in adults with ASD and comorbid intellectual disabilities (Gonthier et al., 2016). Our study broadens these previous findings by suggesting that sensory processing difficulties are positively associated with more behavioral problems (Gourley et al., 2013). In previous research in children with ASD, sensory sensitivity was associated with externalizing behavior in typically developing children (Tseng et al., 2011). Aggression towards others in children with ASD was associated with low registration (Bitsika et al., 2017), whereas aggression was associated with sensory seeking behavior in low-functioning adults with ASD (Gonthier et al., 2016). Our results add to this field of research by showing that reactive and proactive aggression differentially relate to different levels of sensitivity to sensory stimulation and responses to under- or overstimulation. This has clinical relevance as it helps to explain why aggressive behavior is displayed, allowing for an effective substitution by less disturbing coping mechanisms that address sensory issues.

The most robust associations were found between the AASP total score and aggression. This total score has been used in previous research (Horder et al., 2014) and overcomes the problem of collinearity between raw quadrant scores. In our sample, we found that, compared to the normal population, low registration,

sensory sensitivity, and sensory avoiding in adults with ASD tend to be similar or higher, whereas sensory seeking tends to be similar or lower.

Although direct causal inferences cannot be drawn from a cross-sectional study, it is tempting to speculate about underlying mechanisms. Low registration is often described as being marked by missing sensory input and more passive self-regulation strategies. This passivity may induce less involvement in situations in which more externally directed forms of aggressive behavior could occur. However, adults with ASD with low registration may still feel easily overstimulated, by ruminating thoughts for example, which is reflected in higher scores on the internal state of hostility. Interestingly, the more externally directed forms of aggression, i.e., anger as well as proactive and reactive aggression, were all associated with sensory seeking behavior, suggesting that this sensory seeking behavior is to some extent conditional for these types of aggression, or tends to be involved in situations in which these types of aggression can occur. Concerning anger and reactive aggression, the combination of sensory seeking and sensory sensitivity suggests that hypersensitivity is relevant to induce these types of feelings and behavior. Hypersensitivity may function as a trigger for reactive aggression and feelings of anger. With regard to proactive aggression, our results suggest that it is the combination of sensory seeking with low registration—and perhaps associated hostility—that underlies overt aggression in adults with ASD.

Adults with ASD are known to have more sensory processing difficulties compared to the general population (Crane et al., 2009). Our results confirm that individuals with ASD also present with significantly different scores in the quadrants as calculated with the AASP, thus showing differences in the more specific areas of sensory seeking, sensory sensitivity, sensory avoiding, and low registration. By graphical presentation of the calculated neurological threshold and behavioral response (Metz et al., 2019), we offered an innovative view on the sensory profiles in persons with ASD compared to the norm population, which shows that the majority shows a lower neurological threshold and more passive behavioral response.

Detailed measurement of aggressive behavior allowed us to demonstrate that different types of aggressive behavior are related to different aspects of sensory processing. Coarse meshed comparison with previous studies, without possible statistical inference, indicates that the various aggression-related scores in our

sample are relatively similar to those in the general population (Cima et al., 2013; Hornsveld et al., 2009). We found no indication for differences between men and women with ASD. Although we would have expected higher levels of physical aggression in men and, perhaps, higher levels of anger or hostility in women (Österman & Björkqvist, 2018), we did not find evidence for gender-specific vulnerabilities in persons with ASD. The confounding effects of gender were limited—despite demonstrated differences in sensory processing variables—although our analyses were corrected for gender. Our findings indicate gender-related differences in sensory processing, but no significant differences in the magnitude or direction of associations between sensory processing and aggressive behavior. Therefore, we have no indication that the generalizability of our findings to other (clinical) populations with more male persons with ASD would be limited.

Some limitations need to be discussed. First, selection bias could have been present due to differences in commitment to scientific research between therapists, but only when this commitment is related to patient characteristics. However, we found no clear indication that our study sample differed from our source population. Second, our source population at Dimence might not be fully representative of the broad population of adults with ASD, due to the effect of the institution's specializations and expertise. Our source institution provides general mental health care but also accommodates teams specialized in mental health care for normal- to higher-functioning adults with ASD with complex comorbidity, such as forensic–psychiatric problems or addiction. In part, we analyzed the relevance of these factors as potential confounding variables or effect modifiers. In general, our results might be generalizable to the ASD populations of normal- to higher-functioning individuals, including women in both inpatient and outpatient settings. Third, we had no information available on current medication use, which is a possible confounding factor. There is some evidence to suggest that psychotropic medications, e.g., atypical antipsychotics such as risperidone, which is used to treat irritability and maladaptive behavior in children with ASD (Rimmington, 2017), may also impact aspects of sensory processing, either by heightening neurological thresholds or by influencing behavioral response. Finally, the potentially relevant factors ASD severity level and intelligence were not available in our dataset, which may have resulted in unmeasured confounding effects. We used available proxy measurements, respectively treatment setting and educational level.

In sum, clinical practice may benefit from applying detailed assessment of sensory processing problems when treating aggressive behavioral problems in adults with ASD. Therapists and patients may use the sensory profile as an alternative treatment target in case of unexplained or treatment-resistant aggressive behavior. Future research on the added value of the calculated neurological threshold and behavioral response, as well as the mapping of the individual on the model of sensory processing, may further inform clinical practice. Finally, we would recommend replication of our findings in broader populations of (forensic) psychiatric patients, e.g., patients with attention-deficit/hyperactivity disorder or learning disabilities, to further unravel underlying mechanisms in understanding the relation between sensory processing difficulties and aggression.

In our study, we demonstrated the association between sensory processing and aggressive behavior. Evidence was presented for this association on more detailed levels of both sensory processing and aggressive behavior. Additionally, we presented new methods for calculating and presenting the results of the Adolescent/Adult Sensory Profile. Clinical practice may benefit from applying detailed diagnostics on sensory processing difficulties when treating aggressive behavior in adults with ASD.

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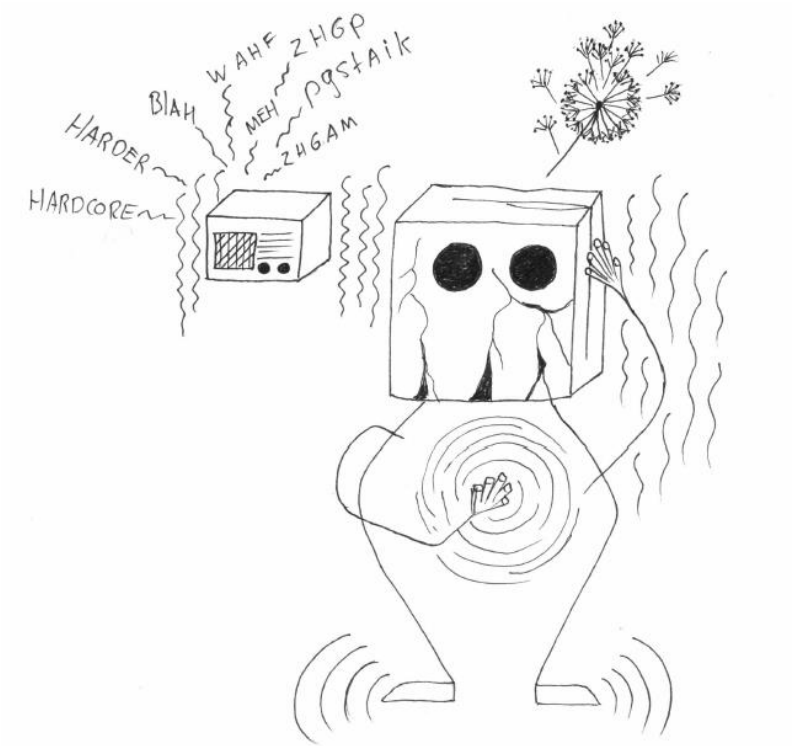
CHAPTER EIGHT

Sensory processing and alcohol use in adults with autism spectrum disorder



A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

Abstract

The association between substance use and autism spectrum disorder (ASD) is complex. Although sensory processing difficulties are highly prevalent in individuals with ASD, data on the association between sensory processing and substance use in ASD are limited. This study aimed to investigate the association between sensory processing patterns and alcohol use in adults with ASD. Kruskal Wallis Tests were performed on questionnaire data (Adolescent/Adult Sensory Profile and Alcohol Use Disorders Identification Test – Consumption) of 101 adults with ASD. Sensory processing difficulties are associated with alcohol use in adults with ASD. Differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern: drinkers reported 6.5 to 8 points higher levels of low registration, non-hazardous drinkers reported 9 points higher levels of sensory sensitivity and hazardous drinkers reported 7.5 points higher levels of sensory seeking, all in comparison with non-drinkers on scales ranging from 15 to 75. Our proof-of-concept study indicates that vulnerability in some individuals with ASD for substance use disorders might be explained by sensory processing difficulties. Whether alcohol is used as 'self-medication' or is associated with other neurobiological vulnerabilities needs further investigation in larger follow-up studies.

Introduction

The association between substance use and autism spectrum disorder (ASD) is complex, with underlying mechanisms incorporating various general and ASD-specific risk and protective factors. General risk factors for substance use, such as familial history, adverse family events or psychological distress, are found to be equally relevant for individuals with ASD as for individuals without ASD, but might be more prevalent in individuals with ASD. Additionally, social impairment and less sensation seeking behavior might be specific risk factors for individuals with ASD (Ressel et al., 2020). Hypothesized etiological and pathophysiological mechanisms for substance use are often focused on the social effects of substance use in relation to social deficits (Brown et al., 1987) or on substance use as a form of self-medication for mental health problems and psychological distress (Khantzian, 1997). Recent qualitative research further identified underlying motivations for substance use in individuals with ASD and results indeed point towards the use of substances to manage behavior and lower mental health symptoms and distress (Weir et al., 2021).

In general, autistic traits include several aspects, such as deficits in social interaction and social communication, as well as restricted, repetitive patterns of behavior. More recently, sensory processing difficulties have been included as discriminating classification criteria for ASD. Sensory processing difficulties are highly prevalent among individuals with ASD and impair functioning in daily life (Crane et al., 2009). Moreover, sensory processing difficulties are found to be associated with substance use disorders (Kelly et al., 2021). However, data on the association between sensory processing and (the broader concept of) substance use within the ASD population are limited. Previous studies on substance use in ASD did not include measurement of sensory processing, or only implicitly assess them as part of more generic instruments for the assessment of ASD. As a result, recent overviews on the topic lack information and were not able to provide suggestions for clinical practice (Ressel et al., 2020). The present study aims to fill this gap and investigates the possible association between sensory processing patterns and alcohol use in adults with ASD.

Methods

Data were collected in outpatient and inpatient populations at locations specialized in neurodevelopmental disorders of Dimence Mental Health Care Institution in the Netherlands between April 2018 and April 2019. All participants provided written informed consent. The eligible population consisted of adult persons in treatment at outpatient or inpatient facilities of Dimence for clinically diagnosed ASD, willing to provide informed consent for participation in the study. The local protocol for the assessment of ASD in adults follows the national guidelines for ASD in adults (Kan et al., 2013), incorporating extensive diagnostic interviews by experienced clinicians. Predefined exclusion criteria were insufficient knowledge of the Dutch language or other difficulties to understand the provided information. A total of 101 adults with ASD ($M_{Age} = 32.9, SD_{Age} = 12.4$; $N_{Male}/N_{Female} = 53/48$) were included in the study. For further details about the procedure and general sample characteristics, we refer to Van den Boogert et al. (2021).

The present study is part of the Sensory Processing and Aggressive behavior in Autism spectrum disorder (SPAA) Study, an observational study in a clinical population. The project was approved by the institutional review board of the Dimence Group (CWO-042018FB). We used the Dutch version of the Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002), a 60-item, self-report questionnaire to obtain information on responsiveness to various sensory stimuli and to identify deficits in the sensory systems that may inhibit the individual to participate in daily activities. The AASP produces four continuous raw quadrant scores ranging from 15 to 75, representing the four quadrants of Dunn's Model of Sensory Processing (Dunn, 1997): low registration (i.e. under-registration of sensory stimuli), sensory seeking, sensory sensitivity, and sensory avoiding. Each quadrant is constructed by 15 items, rated on a 5-point Likert scale from never (1) to always (5). The values of the alpha coefficients for the quadrant scores range from .64 to .78, which is satisfactory.

The Alcohol Use Disorders Identification Test - Consumption (AUDIT-C; Bush et al., 1998) is a 3-item brief screener for hazardous alcohol use. The three items encompass frequency of drinking in the past year, typical quantity of drinks and frequency of heavy drinking. Items are answered on a five-point scale, with possible scores ranging from 0 to 4. As a result, the total score ranges from 0 to 12. Items two and three were only completed by participants who confirmed alcohol consumption

in the past year on the first question. In line with Bowri et al. (2021), we used the AUDIT-C to identify three subgroups: non-drinkers, non-hazardous drinkers and hazardous drinkers. We used item 1 to identify non-drinkers and applied cut-offs ≥4 for men and ≥3 for women (Reinert & Allen, 2007) to label drinkers as hazardous drinkers or non-hazardous drinkers.

All therapists at the institution were extensively informed about the study and requested to select potential participants from their individual caseloads by applying the inclusion and exclusion criteria. Next, all selected patients were provided with the study's information sheet by their own therapist. After sufficient reflection time, the patients were asked to consider participating in the study and, if they agreed, to fill out the informed consent form. Patients who provided informed consent were contacted by a research employee to schedule an appointment for completing the survey. During the appointment, the research employee was available at all times to provide brief verbal instructions and to answer questions. All participants were able to complete the survey. Participation was on a voluntary basis, and the participants received no benefit or compensation.

For all statistical analyses, we used IBM SPSS version 25.0. First, we compared non-drinkers, non-hazardous drinkers and hazardous drinkers on demographic variables using Chi-square tests. Next, assumptions for a Multivariate Analysis of Variance (MANOVA) were tested. Due to the non-normal distribution of sensory processing quadrant scores, we used Kruskal Wallis H tests to investigate the association between the AASP raw quadrant scores of sensory processing and the three subgroups of alcohol use. All statistical tests were two-sided and used a significance level of $p < .05$. Effect size for each Kruskal Wallis H test was calculated and expressed in epsilon-squared. Post-hoc analyses were done by performing Dunn-Bonferroni tests for pairwise comparisons and corrected for multiple comparisons.

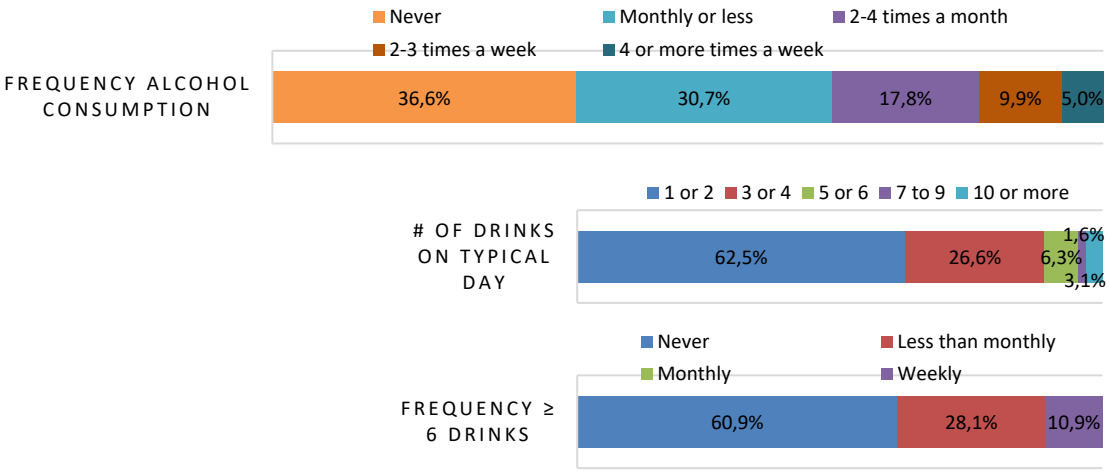
Results

Figure 1 presents sample characteristics based on the AUDIT-C. A relatively high proportion of participants (37%) reported no alcohol consumption at all, over the past year. Almost one third reported drinking alcohol monthly or less frequent. A total of 15% of the sample reported drinking on more than one occasion per week. Within the drinking group, almost two-thirds reports drinking 1 or 2 units on a

typical occasion. Binge drinking (≥ 6 drinks) was reported by 39% of the drinkers. For other general sample characteristics, we refer to Van den Boogert et al. (2021). Differences between non-drinkers ($N = 37$), non-hazardous drinkers ($N = 38$) and hazardous drinkers ($N = 26$) were not statistically significant on the main demographic variables sex ($\chi^2(2) = 2.206, p = .332$), age ($\chi^2(2) = 0.286, p = .867$), and educational level ($\chi^2(4) = 3.573, p = .467$). Outpatients were more often hazardous drinkers and less often non-drinkers than inpatients, with borderline significance ($\chi^2(2) = 6.010, p = .050$).

Figure 1

General sample characteristics for alcohol consumption (AUDIT-C): frequency of alcohol consumption for the total sample and number of drinks on a typical day and frequency of binge-drinking for drinkers.



Median values on low registration were 34.0 for non-drinkers, 40.5 for non-hazardous drinkers, and 42.0 for hazardous drinkers. The difference in low registration between non-drinkers, non-hazardous drinkers and hazardous drinkers was statistically significant, $\chi^2(2) = 12.408, p = .002, \mathrm{E}_R^2 = .124$. Post-hoc analysis revealed that the mean rank scores on low registration of both non-hazardous drinkers ($\chi^2(1) = -17.658, p = .027$) and hazardous drinkers ($\chi^2(1) = -24.692, p = .003$) were higher than the mean rank score of non-drinkers. We found no indication

for a statistically significant difference between non-hazardous and hazardous drinkers on low registration ($\chi^2(1) = -7.034, p = 1.00$).

Median values on sensory seeking were 37.0 for non-drinkers, 40.5 for non-hazardous drinkers, and 44.5 for hazardous drinkers. The difference in sensory seeking between non-drinkers, non-hazardous drinkers and hazardous drinkers was statistically significant, $\chi^2(2) = 6.698, p = .035, \mathrm{E}_R^2 = .067$. Post-hoc analysis showed that the mean rank score on sensory seeking of hazardous drinkers was higher than the mean rank score of non-drinkers ($\chi^2(1) = -19.389, p = .029$). We found no indication that mean rank scores of non-hazardous drinkers differed from non-drinkers ($\chi^2(1) = -8.213, p = .674$) or from hazardous drinkers ($\chi^2(1) = -11.176, p = .401$).

Median values on sensory sensitivity were 42.0 for non-drinkers, 51.0 for non-hazardous drinkers, and 51.0 for hazardous drinkers. Difference in sensory sensitivity between non-drinkers, non-hazardous drinkers and hazardous drinkers was statistically significant, $\chi^2(2) = 6.868, p = .032, \mathrm{E}_R^2 = .069$. Post-hoc analysis showed that the mean rank score on sensory sensitivity of non-hazardous drinkers was higher than the mean rank score of non-drinkers ($\chi^2(1) = -17.153, p = .034$). Mean rank scores of hazardous drinkers did not differ from non-drinkers ($\chi^2(1) = -13.094, p = .242$) or from non-hazardous drinkers ($\chi^2(1) = 4.060, p = 1.00$).

Median values on sensory avoiding were 45.0 for non-drinkers, 52.0 for non-hazardous drinkers, and 48.0 for hazardous drinkers. Difference in sensory avoiding between non-drinkers, non-hazardous drinkers and hazardous drinkers was not statistically significant, $\chi^2(2) = 1.917, p = .383$.

Discussion

Our results demonstrate that sensory processing difficulties are associated with alcohol use in adults with ASD, and that differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern. Drinkers (both hazardous and non-hazardous) reported higher levels of low registration compared to non-drinkers. Moreover, non-hazardous drinkers reported higher levels of sensory sensitivity compared to non-drinkers, whereas hazardous drinkers reported higher levels of sensory seeking compared to non-drinkers. We found no indication of differences in sensory avoiding.

Research on the association between alcohol use, or substance use in general, and sensory processing difficulties is scarce. Recently, Kelly et al. (2021) found comparable results among young people with substance use disorders, with elevated levels of low registration, sensory sensitivity and sensory avoiding compared to the general population. Moreover, in neurotypical young adults, sensory sensitivity was associated with problematic substance use, although through elevated levels of distress (Meredith et al., 2016). However, it is at present unknown whether sensory processing difficulties may result in substance use disorders, or the other way around: some sensory processing difficulties may be increased or caused by substance use. It is tempting to speculate that our study - in a clinical population of individuals with ASD, in which difficulties in sensory processing are a ubiquitous feature - points to a main causal direction from sensory processing difficulties to substance use disorder, but the temporal direction could not be distinguished due to our cross-sectional design.

In our study, we applied the same subgroup definitions as Bowri et al. (2021), identifying non-drinkers, non-hazardous drinkers and hazardous drinkers. Bowri et al. (2021) found a U-shaped pattern among autistic adults, with higher levels of autistic traits among non-drinkers and hazardous drinkers in comparison with non-hazardous drinkers. We did not find such patterns for sensory processing difficulties. Lowest levels of sensory processing difficulties were found in non-drinkers and elevated levels of sensory processing difficulties were found in both non-hazardous as well as hazardous drinkers. We propose two possible explanations. First, within the largely unknown underlying causal mechanism, the severity of sensory processing difficulties might differ from the amount and severity of (other) autistic traits. As Bowri et al. (2021) proposed, greater social communication difficulties may lead to either avoiding social events or more symptomatic distress during social events. Avoiding social events may be accompanied by less alcohol consumption and more prevalent abstinence, and to less sensory input. Engaging in social events might lead to elevated alcohol consumption for reasons of social enhancement or self-medication, and to more sensory input, which in itself also might invoke self-medication. Second, although alcohol use is usually considered as a form of self-medication, alcohol ingestion in itself may influence sensory experiences, such as the vestibular (Tianwu et al., 1995) or visual functions (Watten & Lie, 1996). Alcohol use may not induce the (inborn) vulnerability for sensory processing difficulties, but may still impact on the

neurological threshold or the atypical sensory-based behavior in individuals with ASD.

Some limitations need to be discussed. First, for statistical reasons, we were bound to non-parametrical testing and were not able to control for potential confounding variables, such as age, educational level and treatment setting. Also, because of the limited sample size, we were unable to perform stratified analyses. Second, our study lacked sufficient measurement of other autistic traits and their severity. Therefore, we were unable to provide more detailed suggestions about the underlying causal mechanisms. Third, we did not include a general population or clinical (i.e. ADHD) comparison group. Therefore, we are unable to determine whether the found effects are unique for the ASD population.

Our proof-of-concept study demonstrates that sensory processing difficulties are associated with alcohol use in adults with ASD, and that differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern. Our results indicate that vulnerability for substance use disorders in some individuals with autism spectrum disorder might be explained by sensory processing difficulties. Whether alcohol is used as 'self-medication' or is associated with other neurobiological vulnerabilities needs further investigation in larger follow-up studies.

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CHAPTER NINE

General discussion

A visual interpretation of sensory processing difficulties by a patient residing at FPC De Kijvelanden. Illustrated by creative therapist Danielle Westhoff.

This thesis aimed to investigate the relevance of sensory processing difficulties for forensic psychiatric clinical practice, considering that these difficulties are often reported by patients and observed by clinicians and, at the same time, these difficulties are highly under-investigated within the forensic psychiatric population. Research in other clinical populations already provided first evidence for the association of sensory processing difficulties with behavioral problems that are often treated in forensic psychiatry, such as aggressive and violent behaviors or substance abuse. For the purpose of the described main objective of this thesis, several studies were conducted in order to investigate the association of sensory processing difficulties with psychopathology in general and, more specifically, with externalizing behavior in adult clinical and non-clinical populations. In addition, this thesis contains methodological investigations of clinical instruments developed for the measurement and screening of both sensory processing difficulties and externalizing behavior.

Summary of main results

The first part of this thesis is focused on sensory processing and psychopathology. We investigated how sensory processing difficulties are associated with psychiatric disorders in adolescent and adult populations. In order to address this question, we present a meta-analysis in chapter 2, aggregating data from previous studies that measured sensory processing difficulties using the Adolescent/Adult Sensory Profile (AASP) self-report questionnaire in various psychiatric clinical populations. The analysis demonstrated that these difficulties occur in a broad spectrum of psychiatric conditions and should therefore be considered as a transdiagnostic factor. Moreover, the analysis demonstrated that these difficulties tend to occur in a similar pattern, with increased levels of sensory sensitivity, sensory avoiding and low registration and decreased levels of sensory seeking in comparison with the instrument's general population reference values. However, for the purpose of this meta-analysis, no studies in clinical groups with personality disorders – disorders that are overrepresented in forensic psychiatry (Timmerman & Emmelkamp, 2001) – were identified. In addition, within the scope of the analyses presented in this thesis, we were not able to determine the prevalence of sensory processing difficulties in forensic psychiatric clinical practice. Finally, the meta-analysis was

limited to self-report questionnaire data, leaving out other measurements options (e.g. EEG, observation, interview).

To further investigate whether the interplay between sensory processing difficulties and psychiatric disorders could be explained by stress, we studied, as presented in chapter 3, the association between sensory processing difficulties and stress-related disorders – in particular occupational burnout – in a working population. The results demonstrated the association of sensory processing difficulties with perceived stress levels and burnout symptomatology. However, the exact role of sensory processing difficulties within the clinical context of occupational burnout remains largely unclear. A second question that was discussed within the context of our meta-analysis presented in chapter 2, was whether the reference data of the AASP are accurate. For the purpose of answering this question, we conducted a second meta-analysis integrating data of studies that applied the AASP in general population and non-clinical samples. The results of this second meta-analysis, presented in chapter 4, indicated that the AASP reference data are accurate, although with important exceptions. The reference values for sensory seeking behavior were found to be an overestimation in all investigated age groups. Moreover, young adults disproportionately influenced the adult reference values on all AASP subscales. These results suggest that deviations on sensory seeking should be interpreted with caution and separate reference values for young adults are needed. However, in particular because of the limited effect sizes, these results did not provide clear arguments to reconsider the conclusions of our first meta-analysis.

The second part of this thesis is focused on sensory processing and externalizing behavior. First, in chapter 5, we presented a methodological investigation of screening and measurement options for externalizing behavior in youths. In particular, the Strengths and Difficulties Questionnaire (SDQ) was analyzed for the purpose of early identification of disruptive behavior. Results demonstrated that the SDQ can indeed be used for this purpose in high-risk settings, expanding the screening and measurement options in youths and, as a result, the possibilities for early identification and intervention. In chapters 6 and 7, we presented investigations of the association of sensory processing with aggressive behavior in, respectively, adults with autism spectrum disorder (ASD) and a non-clinical working population. In both studies, we found evidence for the existence of this association, indicating that sensory processing patterns are associated with individual subtypes of aggressive behavior in various combinations. Finally, in

chapter 8, we addressed the question whether and how sensory processing difficulties are associated with substance use, in particular alcohol use, in adults with ASD. Results demonstrated that sensory processing difficulties are associated with alcohol use in adults with ASD and that differences in sensory processing between subgroups based on alcohol consumption vary per specific sensory processing pattern: drinkers reported higher levels of low registration, non-hazardous drinkers reported higher levels of sensory sensitivity and hazardous drinkers reported higher levels of sensory seeking, all in comparison with non-drinkers. This indicates that vulnerability in some individuals with ASD for substance use disorders might in part be explained by sensory processing difficulties.

The results presented here are indicative for the relevance of sensory processing difficulties for forensic psychiatric clinical practice: sensory processing difficulties are indeed transdiagnostically associated with psychopathology in general and associated with aggressive behavior and alcohol use in various clinical and non-clinical populations. Next, the clinical and scientific implications of these results will be discussed from a forensic perspective. Meanwhile, our research group currently aims to quantify the occurrence of sensory processing difficulties and their association with aggressive behavior in a population of forensic psychiatric patients in the *Foretech Study*. This is a longitudinal study in progress among patients treated in outpatient facilities of Transfore, a forensic psychiatric institution in the eastern parts of the Netherlands. The study is aimed at investigating the role and relevance of several neurobiological factors within the context of antisocial and aggressive behavior.

The case of Amy

To further illustrate the clinical relevance of the main associations studied within this thesis and how treatment of aggressive behavior could benefit from extensive assessment of sensory processing difficulties, we first present the case of Amy. This case is part of our qualitative study in progress *SPAA Case Series*. In this study, we aim to explore the role and relevance – as perceived by patients and their therapists – of sensory processing difficulties for the treatment of aggressive behavior.

Amy is a 23-year-old female diagnosed with ASD and in treatment at an inpatient mental healthcare institution specialized in ASD. She was admitted for approximately eight months. Prescribed medications include an antipsychotic, an antidepressant and a psychostimulant. She reported no current substance use. Amy was diagnosed with ASD in 2013, when she was 14-years-old, and also suffers from recurrent depressive episodes. She was repeatedly admitted to inpatient mental healthcare facilities to stabilize after mental crisis. Amy previously studied at a university of applied sciences, but did not obtain her degree due to the described crises and admissions.

One of the main treatment goals for Amy is to improve her abilities to regulate her anger. Amy and her therapist both assume that her anger is often related to rigidity and difficulties with theory of mind: situations in which behavior of others seems incomprehensible and incompatible with her own norms and beliefs almost automatically translate into anger. This anger can evolve into physical aggressive behavior, which is primarily self-directed and often results in severe self-mutilation (e.g. head banging, hitting or kicking walls and doors, scratching and cutting herself). The anger issues are primarily treated with emotion regulation therapy and psychomotor therapy.

Amy reports several types of sensory processing difficulties. She is highly sensitive for various types of sensory input, in particular auditory (e.g. hearing someone eat or vacuum cleaning), visual (e.g. differences between daylight and dark) and tactile (e.g. feeling certain aspects of her clothes). She experiences a visit to the supermarket as problematic in a multisensory way, i.e. due to sounds, lighting, smells. However, she forces herself not to avoid difficult situations and rather chooses to endure them. In addition, Amy can also feel under-stimulated and sometimes shows uncontrolled sensory seeking behavior, mostly proprioceptive (e.g. jumping over a fence or running around). She doesn't know whether and how to manage her sensory processing difficulties. Her therapist, a nurse specialist, acknowledges the importance of sensory processing difficulties in persons with ASD, although her knowledge resulted from her clinical experience and was not part of her education.

For structural and detailed assessment of her sensory processing difficulties, Amy filled out the Adolescent/Adult Sensory Profile questionnaire (Brown & Dunn, 2002). Amy's levels of sensory seeking behavior, low registration (i.e. under-registration of sensory stimuli) and sensory avoiding were within the normal range of the general population. However, she reported much more sensory sensitivity than most people. Item analysis showed

hypersensitive processing of auditory, visual and tactile information and the under-stimulation on the proprioceptive modality.

After four weeks, Amy and her therapist reflected on their use of the provided diagnostic information. At first glance, the report confirmed and detailed her inclination to not avoid and therefore to endure sensory stimulation, despite her high sensitivity for certain stimuli. They talked about how this non-avoidant behavior could lead to anger and how this anger in turn could lead to even higher levels of sensory sensitivity. Amy started to try to regulate her sensory sensitivity by discussing her sensory processing difficulties with other group members. Moreover, the under-stimulation on the proprioceptive modality opened a conversation with her therapist on how anger could be related to proprioceptive under-stimulation, how this under-stimulation could perhaps lead to self-mutilation and, as a result, how sensory seeking behavior could be transformed into more adequate behavior in order to regulate her anger. After twelve weeks, Amy's sensory processing difficulties and their relationship with anger have become more often topic of conversation during therapy. In particular her inclination to not avoid and to endure situations with certain sensory stimuli were discussed. Amy became more aware of her choices in these situations and is working on more acceptance towards dosing of sensory input and, as a result, avoiding certain situations or sensory stimuli. By doing so, she experiences more possibilities to regulate her anger issues and therefore to reduce her self-directed aggressive behavior.

A forensic psychiatric perspective

As described above, the meta-analytical results presented in chapter 2 are limited by a lack of data on sensory processing difficulties in certain psychopathological subgroups. In general, as described in chapter 2, studies measuring sensory processing difficulties in non-neurodevelopmental disorders are scarce. In particular, studies using questionnaires other than the AASP (e.g. Sensory Over-Responsivity Scales (Schoen et al., 2008), Sensory Perception Quotient (Tavassoli et al., 2014), Auditory Attention and Discomfort Questionnaire (Dunlop et al., 2016)) in non-neurodevelopmental disorders were not identified, except for one study which used the SPQ in tic disorders (Isaacs et al., 2020). In certain clinical groups, data is yet unavailable. For instance, in our meta-analysis, no studies in personality disorders were identified. As personality disorders are highly prevalent in forensic psychiatry (Timmerman & Emmelkamp, 2001), data from patients with personality

disorders is much needed, in particular as previous studies in specifically borderline personality disorders already suggest heightened reactivity to sensory stimuli (Brown et al., 2009; Rosenthal et al., 2011). Moreover, several diagnostic subgroups in the meta-analysis presented in chapter 2 were based on a limited number of studies and/or limited sample size. This applies to, for instance, substance use disorders or schizophrenia; disorders that often occur in forensic psychiatry as well. Further research is needed to investigate sensory processing difficulties in all non-developmental diagnoses to confirm their role as a transdiagnostic factor.

Further forensic psychiatric considerations will be discussed by means of the Risk-Need-Responsivity (RNR) model. This is the leading treatment model for offenders and has been of essential influence on the foundations of forensic mental healthcare in most transatlantic countries (Ward et al., 2007). In brief, as its name suggests, the model contains three core principles. The Risk principle represents the important positive relationship between the level of recidivism risk and the necessary level of intervention: individuals with higher recidivism risk will benefit from treatments with higher intensity. The Need principle states that only criminogenic needs – factors that could reduce recidivism risk when treated – should be targeted. The Responsivity principle assumes that interventions should be tailored to the characteristics of the individual in treatment, for instance, learning style or motivation (Bonta & Andrews, 2007). To our knowledge, sensory processing difficulties have not been considered previously within the context of the RNR-model. However, our results indicate that sensory processing difficulties could be a risk factor for violent behavior and related recidivism risk, and may contribute to the assessment of individual recidivism risk, at least in individuals with ASD and perhaps in broader clinical subgroups. These difficulties may not have been considered as a risk factor to date, because of their assumed association with ASD as a specific psychopathological condition. However, our results underline the factor's transdiagnostic character and its association with violent behavior in various clinical and non-clinical populations. We therefore suggest to investigate the predictive value of sensory processing difficulties for violent recidivism. Potentially, these difficulties could have added value in risk assessment for violent recidivism, as is often done using risk assessment tools, such as the HKT-R (Bogaerts et al., 2018) or FARE (Van Horn et al., 2016).

Investigating whether sensory processing difficulties are related to risk of recidivism is at least necessary to determine whether – in individual cases – these difficulties could form a criminogenic need. Criminogenic needs should surely be given priority over non-criminogenic factors, because of their relationship with risk of recidivism (Ward & Stewart, 2003). Sensory over-stimulation, in interplay with other factors, could lead to a fight-or-flight response in order to resolve the experienced over-stimulation (Ayres, 1963). A fight response will lead to impulsive or reactive types of aggressive behavior. On the other hand, being sensory under-stimulated could lead to sensory craving or sensory seeking behavior, described as intense searching for increased stimulation (Miller et al., 2009). This sensory seeking behavior could lead to aggressive behavior indirectly by engaging in situations in which chances of aggressive behavior are increased (e.g. nightlife, substance use) or directly by proactively engaging in aggressive behavior (Raine et al., 2006). In addition to the studies presented in this thesis, more longitudinal research is needed to determine the precise causal relationships in place. Apart from these important theoretical considerations, the main follow-up question is how to address these sensory processing difficulties in clinical practice. We will first discuss several diagnostic complexities, after which we will present some therapeutic considerations.

Initially, within the forensic-psychiatric clinical process, evidence-based diagnostic options of adequate psychometric quality for assessing sensory processing difficulties are of vital importance. As discussed in chapter 2, several diagnostic options for sensory processing difficulties in adolescent and adults are already available. The AASP is the most frequently used self-report questionnaire for this purpose in adolescent and adults with ASD (DuBois et al., 2017) and was the instrument of choice in all studies presented in this thesis. However, other self-report questionnaires are available as well, such as the Sensory Perception Quotient (SPQ; Tavassoli et al., 2014) or the Glasgow Sensory Questionnaire (GSQ; Kuiper et al., 2019). Some important aspects of these questionnaires limit their applicability in present day mental healthcare or specifically forensic mental healthcare. As we described in chapter 4, the AASP was published in 2002 (Brown & Dunn, 2002). Given the societal developments during the last twenty years, the items lack assessment of new environmental stimuli. In particular, the omnipresent online stimuli (e.g. social media, gaming, websites) are not yet part of the AASP or, to our knowledge, of any other questionnaire assessing comparable constructs. However,

various studies already demonstrated the relationship between screen time and cognitive functioning (Neophytou et al., 2021) and affective functioning (Maras et al., 2015), indicating the high relevance of online stimuli for mental health in general and thus potentially for sensory processing difficulties. Moreover, in the same chapter, we argue that these instruments should develop and provide reference group data of young adults and other adults separately. Similarly, to our knowledge, no reference data are available for forensic psychiatric populations as well. In addition, there is need for a questionnaire (self-report or informant) for inpatient facilities, assessing sensory stimuli that are related to these specific environments (e.g. lighting and acoustics on the ward, talking or laughing by fellow patients or staff members, loud music, lack of activity). Because items on the AASP are in part related to general societal activities (e.g. music events or shopping), filling out the AASP by inpatients – in particular forensic psychiatric patients or prisoners – could lead to underestimation of sensory processing difficulties. Future research addressing these methodological issues is needed.

Apart from methodological issues, we also encountered conceptual challenges while applying the AASP. The questionnaire is based on the Model of Sensory Processing (Brown et al., 2001; Tomchek & Dunn, 2007), containing the four concepts regarding the processing of sensory stimuli: low registration, sensory seeking, sensory sensitivity and sensory avoiding. It is important to consider how these sensory-related concepts overlap with psychiatric terminology. For instance, low registration refers to missing of sensory stimuli, such as streets names. Perhaps this concept of low registration in part overlaps with cognitive problems, such as lowered attention or concentration, that are often seen in psychopathology (e.g. depressive disorder or PTSD). Similarly, sensory seeking behavior might be a behavioral proxy of anhedonia, a core symptom of depressive disorder. In summary, although the AASP is a valid questionnaire for the measurement of sensory processing in daily functioning (Pearson Education, 2008), it is important to further investigate and consider these conceptual challenges when using the AASP in clinical populations.

Diagnostic options other than self-report questionnaires for assessing sensory processing difficulties have been subject for investigation, such as psychophysical measurements, observations, interview or neuroimaging (DuBois et al., 2017). For instance, Davies and Gavin (2007) investigated EEG techniques for the

purpose of validating the proposed diagnosis of Sensory Processing Disorder (SPD) and demonstrated that brain processing in children with SPD differ from typically developing children. As a result, EEG could contribute to the diagnostics for SPD, although more research is needed. Thorough diagnostics are necessary for effective interventions. I therefore suggest to investigate and develop a multi-informant diagnostic set of instruments for sensory processing difficulties in adolescents and adults that combines self-report questionnaire and semi-structured interview data, with informant data, data from clinical observation and, if available, neuroimaging data, in order to validly assess these sensory processing difficulties and that is applicable to, and therefore the instrument of choice in, all clinical and non-clinical populations. First, this would entail the (further) development of several necessary and proven valid and reliable instruments for sensory processing diagnostics in adolescents and adults, in addition to existing self-report questionnaires: a self-report semi-structured interview, an informant questionnaire, an observation scale and neuro-imaging techniques (e.g. EEG). Second, the added value in terms of combined predictive validity and reliability should be investigated in various populations. Third, follow-up studies should provide reference group data for the multi-informant diagnostic set of instruments from various clinical and non-clinical populations. Fourth, the set of instruments should be made available in various languages.

Before considering sensory processing difficulties as an individual forensic need, it is important to determine whether these difficulties form a static or dynamic (i.e. changeable) factor. In chapter 3, we discuss the mere static concept of sensory processing sensitivity (SPS), which is proposed to be a genetically determined trait characterized by deepened cognitive processing of stimuli that is driven by higher emotional reactivity (Aron et al., 2012). Given the genetic basis and personal traits that fundaments the concept, this may concern a more static factor related to the processing of sensory stimuli. However, SPS is considered to be unrelated to SPD (Aron & Aron, 1997). Sensory processing difficulties are more driven by the type of sensory stimuli and the behavioral response to this incoming information (Tomchek & Dunn, 2007) and is more dynamic over age (Humes et al., 2013), as we also demonstrated in chapter 4 that sensory processing evolves from adolescence into (young) adulthood. However, more research is needed to determine the precise dynamic characteristics of sensory processing difficulties. For instance, in chapter 3 we demonstrated the association between sensory processing difficulties and

burnout symptoms. One important follow-up question, namely how these constructs are causally related, is related to the stability of sensory processing difficulties: do sensory processing difficulties form a more stable vulnerability for burnout or do they arise in a more dynamic manner as part of burnout symptomatology?

Although research on this topic is scarce, sensory processing difficulties may influence the individual responsivity to forensic psychiatric treatment. For instance, individuals with ASD often experience how these difficulties are not discussed during therapy or how therapy rooms can be full of overwhelming stimuli (e.g. acoustics, clock ticking, noises from outside, bright lights; Verkes et al., 2021). Given that these difficulties could be considered as a transdiagnostic factor, these therapeutic limitations are perhaps relevant for other clinical groups as well. Moreover, problems regarding responsivity are likely not to be limited to psychological interventions and could also apply to sociotherapeutic interventions: forensic psychiatric units are known to produce many types of sensory stimuli (e.g. loud conversations, loud music, cigarette smoking, bright lights, walls painted in bright colors). It is yet unknown how these stimuli influence the responsivity to sociotherapeutic interventions. More research is needed on the relationship between sensory processing difficulties as a transdiagnostic factor and the individual responsivity to interventions offered in forensic psychiatry.

Clinical recommendations

If sensory processing difficulties indeed form an amenable criminogenic or non-criminogenic factor in need for forensic psychiatric treatment or are a factor influencing responsivity to forensic psychiatric treatment, the available options for interventions should be considered. Well-researched interventions targeted on sensory processing are particularly available within occupational therapy and specifically for children with ASD. Within this context, two types of interventions are available: sensory integration therapy and sensory-based interventions. The former is child-directed and uses play activities and sensory enhanced interactions to improve the child's adaptive behavior. The latter is adult-directed (i.e. parent, caretaker or teacher) and intended to improve behaviors associated with sensory processing difficulties. In particular sensory integration therapy is found to be

effective in reducing behavioral problems related to these difficulties in children with ASD (Case-Smith et al., 2015). However, to our knowledge, evidence-based interventions for sensory processing difficulties in adolescents and adults with ASD or other clinical diagnoses are yet unavailable.

A promising intervention developed for sensory processing difficulties in adults is the Adult Sensory Integration Timmerman Treatment (ASITT) protocol, originally developed for individuals with acquired brain injury (Bakker-Timmerman, 1999). It is largely an adjustment of the sensory integration therapy for children, which is based on A. Jean Ayres' sensory integration theory (Ayres, 1972). The core principle of the ASITT states that sensory stimuli should not be avoided, but carefully and consciously managed. The protocol offers several strategies, techniques and exercises, for instance aimed at compensation for or habituation to sensory stimuli in daily life. Although the protocol was not developed for the clinical psychiatric population and its effectiveness has not been investigated, its core principle and interventions could intuitively be applicable to psychiatric populations as well. For instance, from a forensic psychiatric perspective, integrating these interventions in aggression regulation treatment as usual could be considered and investigated. The Dutch version of aggression regulation therapy offers interventions on several factors known to be related to aggressive behavior (e.g. stress, emotion regulation, impulse control; Hoogsteder et al., 2014). If sensory processing difficulties prove to be a relevant and treatable factor within the context of aggressive behavior, the ASITT-protocol offers applicable interventions for integration in aggression regulation therapy.

The former considerations raise several new questions with regard to the involvement of various professions. Assuming the relevance of these interventions for forensic psychiatry, are sensory processing related interventions reserved for application by occupational therapists and, if so, are there occupational therapists available within (forensic) mental healthcare? The answer to the first question is partly dependent on the recognition sensory processing difficulties will eventually receive from the fields of psychiatry and clinical psychology. Attention for this topic among psychiatrist and clinical psychologists may already have risen since the inclusion of these difficulties within the DSM criteria for ASD in 2013 (American Psychiatric Association, 2013). If sensory processing difficulties are, for instance, widely considered to be a transdiagnostic factor for psychopathology in general,

included in the criteria for other diagnoses or recognized as a separate disorder (i.e. SPD), psychiatrists and clinical psychologists may be even more inclined to lead clinical-scientific investigation of these difficulties. With regard to the second question, our scope is limited to the situation in the Netherlands. A factsheet published by the Dutch association for occupational therapy learns that some occupational therapists working in mental healthcare experience reduction of employed hours in recent years (Zwart et al., 2021). Explanations are found in the limited knowledge about the relevance of occupational therapy for mental healthcare and the unavailability of evidence-based interventions. Although data on employment of occupational therapists within Dutch forensic psychiatry are scarce, it is our personal experience that most institutions lack the availability of these professionals and, as a result, of standard knowledge about sensory processing.

Apart from psychotherapy and pharmacotherapy, sensory processing interventions could also be part of sociotherapy and environmental interventions, in particular in inpatient settings. We argue that a minimum standard of sensory wellbeing for each individual – patients and staff members – should be part of standard policies on forensic psychiatric units. For this purpose, we distinguish interventions regarding human or environmental sensory factors. Human sensory factors include all forms of sensory input experienced by a person that is produced by other persons present within the proximal personal environment. In the context of a forensic psychiatric unit, this input could for example result from: music played in neighboring rooms, conversations in the living room, slamming doors, table manners, cigarette smoking or personal hygiene. Rules and guidelines could be applied to regulate this mutual sensory input in order to ensure each individual's sensory wellbeing. For instance, music played in rooms could be restricted to certain hours and to a limited volume, smoking could be banned from the unit and rules on table manners and personal hygiene could minimize nuisance. To reduce chances of new conflicts arising from new rules, it is vital to assure rule clarity and consistency and clear communication (Alexander et al., 2004).

Environmental sensory factors include all non-human factors within the personal surroundings that produce or influence the sensory input experienced by a person. Ulrich and colleagues (2018) provide a conceptual model aimed at reducing stress and aggression in psychiatric wards, consisting of ten stress reducing design features. These features include several generic sensory-related factors, such

as noise reducing design, daylight exposure and color use. Specific adjustments in psychiatric wards could be made to further ensure each individual's sensory wellbeing. For instance, architectural adjustments could improve acoustics, lighting and coloring in new and existing facilities, air quality control could be applied to minimize smells (Devlin, 1992), window coverings could be improved to control natural lighting and dimmable lights could be installed to control artificial lighting in personal spaces (Canazei et al., 2022).

A special sensory-based facility is the sensory room or comfort room. This is a specialized room within a (mental) healthcare facility designed to benefit relaxation and self-organization (Champagne & Sayer, 2003; Champagne & Stromberg, 2004; Cummings et al., 2010). It usually contains materials and furniture designed to provide sensory input to the proprioceptive, vestibular, tactile, olfactory, gustatory, auditory, and visual modalities (e.g. beanbags, weighted blankets, rocking chairs, rocking chairs, natural pictures; Champagne & Sayer, 2003; Wiglesworth & Farnworth, 2016). Although qualitative research indicate that the use of sensory rooms in forensic mental health facilities could reduce stress, more quantitative research is necessary to determine how the use of sensory rooms is related to aggressive behavior and could, for instance, reduce violent incidents and seclusion or restraint (Wiglesworth & Farnworth, 2016).

Finally, in recent years, various eHealth techniques have been developed and applied within forensic mental healthcare, such as virtual reality, web-based interventions or telepsychiatry (Kip et al., 2018). However, it is yet unknown how sensory processing difficulties influence the experience and effectiveness of these interventions. For instance, experiencing virtual reality results in high levels of multisensory input and, in case of elevated sensitivity to sensory input, the aimed outcome of the intervention could be limited as a result. Ergo, the responsiveness of these interventions could perhaps be influenced by sensory processing difficulties. It may therefore be beneficial to assess these difficulties before applying certain eHealth techniques. Apart from responsiveness to eHealth interventions, first initiatives demonstrate how virtual reality techniques could be used to assess (Koirala et al., 2021) or treat (Rossi et al., 2019) sensory processing difficulties. These interventions could be beneficial for forensic mental healthcare as well. However, more research is needed on sensory processing difficulties in relation to eHealth in forensic mental healthcare.

Concluding remarks

This thesis aimed to investigate the relevance of sensory processing difficulties for forensic psychiatric clinical practice. The results presented are indicative for the relevance of sensory processing difficulties for forensic psychiatric clinical practice: sensory processing difficulties are indeed transdiagnostically associated with psychopathology in general and associated with aggressive behavior and alcohol use in various clinical and non-clinical populations. From these new perspectives, we advise forensic and non-forensic mental healthcare to consider sensory processing difficulties as a relevant factor when treating aggressive behavior. Furthermore, we urge all clinical fields involved within forensic mental healthcare to further investigate the relevance of these difficulties in a scientific manner, enabling their optimal assessment and treatment within our complex forensic psychiatric clinical practice.

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ADDENDUM

Summary

Samenvatting

Portfolio

Manuscripts

Curriculum vitae

Dankwoord

Summary

Sensory processing includes receiving, modulating, integrating and organizing of sensory stimuli, and producing a behavioral response to these stimuli. It involves all information received through the various sensory modalities, for instance visual, auditory, olfactory, gustatory, tactile, vestibular, proprioceptive or interoceptive information. Difficulties in sensory processing are highly prevalent with autism spectrum disorder (ASD) and are part of the diagnostic criteria for ASD presented in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5). Moreover, these difficulties are increasingly associated with other types of psychopathology as well. Sensory processing difficulties have also been associated with various behavioral problems, in particular internalizing behaviors. With respect to the association of sensory processing difficulties with more externalizing behaviors, such as aggressive or violent behavior, research in adolescent and adult populations is far more limited. The research presented in this thesis was conducted to explore the relevance of sensory processing difficulties for (forensic) psychiatric clinical practice, both from a psychopathological and behavioral perspective. Several studies were performed to investigate the association of sensory processing difficulties with psychiatric disorders and with externalizing behavior in adolescent and adult clinical and non-clinical populations. In addition, the thesis contains methodological investigations of clinical instruments developed for the measurement and screening of sensory processing difficulties or externalizing behavior.

In **part one**, we studied the association between sensory processing and psychopathology. In **chapter two**, we examined the sensory processing patterns of adolescent and adult individuals with a broad spectrum of different psychiatric conditions. By comparing diagnostic subgroups to the corresponding reference group of the Adolescent/Adult Sensory Profile (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. Sensory processing difficulties could therefore 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. We discuss the possible relevance of stress within this association as well the necessity to assess the accuracy of the AASP's reference data.

In **chapter three**, we investigated the association between sensory processing patterns, perceived stress and occupational burnout as a stress-related condition in a working population. We focused on different aspects of sensory processing and used the momentum of a particularly stressful period: during the first months of the global COVID-19 crisis. Our results demonstrated that higher scores on sensory sensitivity and low registration were associated with higher scores on perceived stress and core burnout symptoms. Sensory hypersensitivity was also associated with more secondary burnout symptoms. Associations were not driven by underlying sensory-related disorders (e.g., ASD or ADHD). Sensory processing difficulties are relevant predictors of stress and occupational burnout, also in healthy employees. We discuss how this phenomenon warrants further attention, as relatively simple adjustments in working environment may possess important preventive effects.

In **chapter four**, we compared AASP data across studies from the general population to the original AASP reference data, using aggregated data from 30 selected empirical studies in adolescents, young adults, adults and elderly. On the sensory seeking quadrant, all general population age groups scored significantly lower than the reference values provided in the instrument's manual. Furthermore, young adults disproportionately influenced the mean scores on all quadrants. In young adults, scores on sensory sensitivity and sensory avoiding significantly differed from the reference values presented in the AASP manual. Our results suggest that deviations on sensory seeking should be interpreted with caution and that separate reference values for young adults are needed.

In **part two**, we investigated the association between sensory processing and externalizing behavior. First, in **chapter five**, we examined the predictive validity of the self-reported Strengths and Difficulties Questionnaire (SDQ) on disruptive behavior disorders and delinquency, measured with multi-informant questionnaires and structured interviews. We compared three scoring methods: total, subscale, and dysregulation profile scoring. In this high-risk sample, SDQ subscale scores predicted disruptive behavior outcomes best. Predictive values for specific types of delinquency were small. We conclude that the SDQ can be used in high-risk settings for early identification of youth with disruptive behavior.

In **chapter six**, we investigated the direct association between sensory processing and aggressive behavior in adults with ASD. Our results revealed that sensory processing difficulties are associated with more aggressive behavior, more proactive and reactive aggression, more physical and verbal aggression, and more

anger and hostility. Evidence was found for an interaction of the neurological threshold and behavioral response on total aggression and hostility. Participants with higher scores in comparison to the norm group in sensory sensitivity had the highest risk of aggressive behavior. We discuss how clinical practice may benefit from applying detailed diagnostics on sensory processing difficulties when treating aggressive behavior in adults with ASD.

In **chapter seven**, we examined the relationship between sensory processing patterns and aggressive behavior in a healthy working population. Individuals who reported higher levels of underregistration of sensory stimuli also reported higher levels of total aggression, hostility and verbal aggression. Overregistration of sensory stimuli (sensory sensitivity) was associated to higher levels of anger. Our results demonstrate that this association between sensory processing difficulties and aggressive behavior is indeed a broader phenomenon crossing the borders of clinical (ASD) to non-clinical populations. From our perspective, future research should focus on the prevalence of sensory processing difficulties and their relationship with aggressive behavior in forensic mental healthcare.

In **chapter eight**, we investigated the association between sensory processing patterns and alcohol use in adults with ASD. Sensory processing difficulties were found to be associated with alcohol use in adults with ASD. Moreover, differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern. These results indicate that vulnerability in some individuals with ASD for substance use disorders might be explained by sensory processing difficulties. Whether alcohol is used as 'self-medication' or is associated with other neurobiological vulnerabilities needs further investigation in larger follow-up studies.

In **chapter nine**, the main findings presented in this thesis are discussed from a forensic perspective, providing clinical implications and suggestions for future research.

Samenvatting

Sensorische of zintuiglijke prikkelverwerking omvat het ontvangen, reguleren, integreren en organiseren van sensorische informatie, alsmede het vormen van een adequate gedragsrespons op deze informatie. Er zijn acht sensorische gebieden: visueel, auditief, tactiel, smaak, geur, balans, beweging en informatie vanuit het lichaam zelf. Problemen in de verwerking van sensorische informatie worden vaak gezien bij mensen met een autismespectrumstoornis (ASS) en zijn sinds 2013 ook onderdeel van de criteria voor een ASS-classificatie in de vijfde versie van de *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5). Daarnaast wordt sensorische prikkelverwerkingsproblematiek in toenemende mate geassocieerd met andere vormen van psychopathologie; tot op heden met name internaliserende problematiek. De associatie met externaliserende gedragsproblematiek, zoals agressief of gewelddadig gedrag, is slechts in beperkte mate wetenschappelijk onderzocht. De onderzoeken die onderdeel zijn van dit proefschrift zijn uitgevoerd om de relevantie van sensorische prikkelverwerkingsproblematiek voor de (forensisch) psychiatrische klinische praktijk te onderzoeken, zowel vanuit een psychopathologisch als een gedragsmatig perspectief. Er zijn in het kader van dit proefschrift verschillende onderzoeksprojecten opgezet om de associatie van sensorische prikkelverwerkingsproblematiek met psychiatrische stoornissen en met externaliserend gedrag te onderzoeken in adolescenten en volwassenen en in zowel klinische als niet-klinische populaties.

Het **eerste deel** van dit proefschrift gaat over de associatie tussen sensorische prikkelverwerkingsproblematiek en psychopathologie. In **hoofdstuk twee** presenteren we resultaten van een meta-analytisch onderzoek naar sensorische prikkelverwerkingspatronen in een breed spectrum van psychiatrische stoornissen bij adolescenten en volwassenen. We vonden dat vrijwel alle psychiatrische stoornissen gepaard gaan met meer gebrekkige registratie, meer prikkelgevoeligheid, meer prikkelvermijdend gedrag en minder prikkelzoekend gedrag, in vergelijking met de normgroepgegevens van de Adolescent/Adult Sensory Profile (AASP). Hierbij werden over het algemeen grote tot zeer grote effectgroottes gevonden. Sensorische prikkelverwerkingsproblemen kunnen derhalve beschouwd worden als een aspecifiek, transdiagnostisch fenotype dat geassocieerd is met een breed spectrum aan psychiatrische stoornissen. Vervolgonderzoek naar de rol en relevantie van deze problematiek bij psychopathologie kan mogelijk psychiatrische behandeling en prognose verbeteren.

We bespreken ook de mogelijke relevantie van stress bij deze associatie, alsmede het belang van representatieve normdata voor de AASP.

In **hoofdstuk drie** onderzoeken we de associatie tussen sensorische prikkelverwerkingspatronen, stress en burn-out in een groep professionals. De metingen zijn uitgevoerd in een stressvolle periode: gedurende de eerste maanden van de COVID-19 crisis. De resultaten laten zien dat hogere scores op prikkelgevoeligheid en gebrekkige registratie geassocieerd zijn met subjectieve stress en kernsymptomen van burn-out. Hogere prikkelgevoeligheid was tevens geassocieerd met meer secundaire symptomen van burn-out. Hierbij waren eventueel aanwezige prikkelverwerkingsgerelateerde stoornissen (bv. ASS of ADHD) niet van doorslaggevende invloed. Sensorische prikkelverwerkingsproblematiek is dus relevant bij stress en burn-out. We bespreken in het hoofdstuk waarom dit fenomeen meer aandacht verdient, waarbij bijvoorbeeld simpele aanpassingen van de werkomgeving al belangrijke preventieve effecten teweeg kunnen brengen.

In **hoofdstuk vier** zijn AASP-data uit studies in de algemene populatie vergeleken met de normgegevens van het instrument. Hiervoor werden 30 empirische studies in adolescenten, jongvolwassenen, volwassenen en ouderen geselecteerd. In alle leeftijdsgroepen werden voor prikkelzoekend gedrag gemiddelde scores gevonden die lager liggen dan de bijbehorende normscores. Daarnaast werd gevonden dat de gemiddelde scores van de totale groep van volwassenen, op alle kwadranten van de AASP, disproportioneel beïnvloed worden door de scores van jongvolwassenen. De scores op prikkelgevoeligheid en prikkelvermijdend gedrag verschillen bij jongvolwassenen significant van de normscores. We concluderen dat verschillen op prikkelzoekend gedrag met voorzichtigheid moeten worden geïnterpreteerd en dat er separate AASP normgegevens voor jongvolwassenen nodig zijn.

Het **tweede deel** van dit proefschrift gaat over de associatie tussen sensorische prikkelverwerking en externaliserend gedrag. In **hoofdstuk vijf** wordt een onderzoek gepresenteerd naar de predictieve validiteit van de zelfrapportagevragenlijst Strenghts and Difficulties Questionnaire (SDQ) voor disruptieve gedragsstoornissen en delinquent gedrag, zoals gemeten met multi-informantenvragenlijsten en gestructureerde interviews. In dit onderzoek zijn drie scoringsmethoden vergeleken: op basis van totaalscore, subschaalscores of een disregulatieprofielscore. In de populatie jongeren met overrepresentatie van jongeren met gedrags- en emotionele problemen blijken de subschaalscores

disruptief gedrag het beste te voorspellen. De predictieve waarde voor specifieke vormen van delinquent gedrag is beperkt. We concluderen dat de SDQ gebruikt kan worden voor vroegsignalering van disruptief gedrag.

In **hoofdstuk zes** worden resultaten gepresenteerd van onderzoek naar de associatie tussen sensorische prikkelverwerking en agressief gedrag in volwassenen met ASS. Sensorische prikkelverwerkingsproblematiek is geassocieerd met meer agressief gedrag in het algemeen, met proactief en reactief agressief gedrag, met fysieke en verbale agressie, met boosheid en met vijandigheid. Ook zijn er aanwijzingen voor een interactie van de in dit onderzoek berekende neurologische drempel en gedragsrespons in relatie tot agressief gedrag en vijandigheid. Personen met hogere scores op prikkelgevoeligheid hebben het hoogste risico op agressief gedrag. We bespreken hoe de klinische praktijk baat zou kunnen hebben bij het toepassen van prikkelverwerkingsdiagnostiek bij het behandelen van agressief gedrag in volwassenen met ASS.

In **hoofdstuk zeven** onderzoeken we de associatie tussen sensorische prikkelverwerking en agressief gedrag in een populatie werkenden. Personen met meer gebrekkige registratie rapporteren ook meer agressief gedrag in het algemeen, meer vijandigheid en meer verbale agressie. Prikkelgevoeligheid is positief geassocieerd met meer boosheid. Hiermee laten we zien dat de associatie tussen sensorische prikkelverwerking en agressief gedrag een breder fenomeen is dat zich naast klinische (ASS) populaties ook in niet-klinische populaties voordoet. We beargumenteren dat vervolgonderzoek naar dit fenomeen zich zou kunnen richten op populaties gekenmerkt door hoge prevalentie van agressieve gedragingen, zoals in de forensische psychiatrie het geval is.

In **hoofdstuk acht** presenteren we de resultaten van onderzoek naar de associatie tussen sensorische prikkelverwerking en alcoholgebruik in volwassenen met ASS. Hieruit blijkt dat sensorische prikkelverwerkingsproblematiek geassocieerd is met alcoholgebruik in volwassenen met ASS. Hierbij verschilt de sensorische prikkelverwerking tussen alcohol-gerelateerde subgroepen per specifiek prikkelverwerkingspatroon. De resultaten laten zien dat de kwetsbaarheid in sommige volwassenen met ASS voor stoornissen in middelengebruik wellicht verklaard zou kunnen worden door sensorische prikkelverwerkingsproblematiek. Of alcohol gebruikt wordt als zelfmedicatie voor deze problematiek of wellicht geassocieerd is met andere kwetsbaarheden is (bijvoorbeeld om zintuiglijke prikkels te dempen) onderwerp van vervolgonderzoek.

Ten slotte, in **hoofdstuk negen** worden de hoofdresultaten van de onderzoeken in dit proefschrift bediscussieerd vanuit een forensisch perspectief, waarbij klinische implicaties en suggesties voor vervolgonderzoek uitgebreid uiteen worden gezet.

Portfolio

Name Ph.D. Student:	Frank van den Boogert
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Training and activities

M.Sc. in Clinical Epidemiology	NIHES	2017 – 2019	70 ECTS
Patient Oriented Research	Erasmus MC	2017	0.3 ECTS
Good Clinical Practice (BROK)	EMWO	2017	1.5 ECTS
Research Integrity	Erasmus MC	2017	0.3 ECTS
BKO Course Teach the Teacher I	Erasmus MC	2017	16 hours
BKO Workshop Omgaan met groepen	Erasmus MC	2017	4 hours
Sensorische informatieverwerking	Pearson	2017	8 hours

Scientific presentations

IAFMHS Conference	Antwerp, Belgium	2017
Supporting Health by Technology	Enschede, the Netherlands	2018
Science Meeting Erasmus MC	Rotterdam, the Netherlands	2018
Science Meeting Dimence	Deventer, the Netherlands	2019
IAFMHS Conference	Online	2021
Festival Forensische Zorg	Online	2021
Science Meeting Erasmus MC	Rotterdam, the Netherlands	2022
Science Meeting Fivoor	Poortugaal, the Netherlands	2022
Science Meeting De Kijvelanden	Poortugaal, the Netherlands	2022

Supervision and teaching

Lectures:

- iBerry Study internship lectures	Erasmus MC
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Master's thesis supervision:

- N. Brouwer, Psychology	University of Twente
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Manuscripts

published or submitted, in order of the chapters of this thesis:

Van den Boogert, F., Klein, K., Spaan, P., Sizoo, B., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2022). Sensory processing difficulties in psychiatric disorders: A meta-analysis. *Journal of psychiatric research*, *151*, 173-180.

Van den Boogert, F., Spaan, P., Sizoo, B., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2022). Sensory processing, perceived stress and burnout symptoms in a working population during the COVID-19 crisis. *International Journal of Environmental Research and Public Health*, *19*(4), 2043.

Van den Boogert, F., de Bart, I., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2022). *Development of sensory processing across life stages: a meta-analysis evaluating the Adolescent/Adult Sensory Profile reference values* [Manuscript submitted for publication].

Spaan, P., van den Boogert, F., Grootendorst – Van Mil, N. H., Hoogendijk, W. J. G., & Roza, S. J. (2022). *Screening for Disruptive Behavior in Adolescents at Risk Using the Strengths and Difficulties Questionnaire* [Manuscript submitted for publication].

Van den Boogert, F., Sizoo, B., Spaan, P., Tolstra, S., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2021). Sensory processing and aggressive behavior in adults with autism spectrum disorder. *Brain sciences*, *11*(1), 95.

Van den Boogert, F., Spaan, P., Sizoo, B., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2022). *Sensory processing and aggressive behavior in a worker population* [Manuscript submitted for publication].

Van den Boogert, F., Sizoo, B., Bouman, Y. H. A., Hoogendijk, W. J. G., & Roza, S. J. (2022). *Sensory processing and alcohol use in adults with autism spectrum disorder* [Manuscript submitted for publication].

Curriculum vitae

Frank van den Boogert was born on June 28, 1984 in Rotterdam, the Netherlands. He passed his pre-university education in 2002. In the same year, he started his first – prematurely discontinued – study attempts, after which he started working at the Erasmus MC in Rotterdam in 2006; first as an administrative assistant and during the following years as a project manager and financial consultant. In 2012, in addition to his financial position at the Erasmus MC, Frank started his Psychology studies at the Erasmus University Rotterdam. He received his B.Sc. degree in 2015 and his M.Sc. degree (cum laude) in 2017, both in Clinical Psychology. During his Master's, Frank completed his scientific internship at the iBerry Study, a longitudinal cohort study at the Erasmus MC's Department of Psychiatry, and his clinical internship at PsyQ in Spijkenisse. He also participated in the faculty's Advanced Research Program. In 2017, Frank started the work described in this thesis at the Erasmus MC's Department of Psychiatry, conducting several scientific projects in close collaboration with Transfore in Deventer and financially endowed by the Stichting Vrienden van Oldenkotte. In addition to these projects, he received his M.Sc. degree in Clinical Epidemiology in 2019, supervised sixteen bachelor and master student projects and worked as a psychologist at Zonnehuisgroep in Vlaardingen in 2018 and 2019 and at Fivoor FPC De Kijvelanden in Poortugaal since 2021.