Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-025-06924-7

ORIGINAL ARTICLE

Using Psychoacoustic Tasks and Multidimensional Questionnaires to Characterize Auditory Hyperreactivity in Autistic Young People

Patrick Dwyer[1,2,3,4] · **Andre Sillas**[1] · **Falco Enzler**[5,6] · **Arnaud J. Noreña**[5] · **Clifford D. Saron**[1,3] · **Susan M. Rivera**[1,2,3,7]

Accepted: 4 June 2025

Abstract

Prior studies of auditory hyperreactivity in autism have often not distinguished between different aspects of auditory sensory discomfort, such as hyperacusis and misophonia. The present study rigorously characterises multiple forms of auditory sensory hyperreactivity, using a mixture of laboratory-based psychoacoustic tasks and self- and caregiver-reported questionnaires, and examines group differences and relationships among different measures. 18 autistic and 22 comparison adolescents rated the pleasantness of conventionally-pleasant, conventionally-unpleasant, and misophonic trigger sounds at intensities of 50 through 80 dB SPL. They also provided hearing thresholds, loudness discomfort levels, and filled out a number of questionnaires; their caregivers completed additional questionnaires. Autistic participants rated conventionally-pleasant sounds as being more unpleasant at intensities of 60 through 80 dB, but overall loudness discomfort caused by pure tones did not significantly differ across groups, nor did ratings of common misophonic triggers appear to differ. Autistic participants nevertheless self-reported more auditory hyper-reactivity, including hyperacusis and misophonia. However, in the autism group, self-reported auditory hyper-reactivity scores were unexpectedly lower than caregiver-reported scores. Psychoacoustic task and some questionnaire-based measures of misophonia converged well, but hyperacusis measures did not converge well. Sound intolerance reportedly affected autistic participants' quality of life. However, varied findings with different measures, such as ratings of pure tones versus conventionally-pleasant sounds, emphasise the complexity and seeming idiosyncrasy of sensory discomfort and distress in autism. Psychoacoustic sound rating tasks showed some convergence and some divergence with questionnaire measures, pointing to the importance of multimodal measurement.

Keywords Misophonia · Hyperacusis · Sound intolerance · Sensory hyperreactivity · Sensory overload

Introduction

Sensory differences in autism are highly impactful, being related to anxiety (Green et al., 2012), sleep problems (Tzischinsky et al., 2018), and diet (Chistol et al., 2018). Aversive sensory stimulation can interfere with autistic people's social interactions and processing (Green et al., 2018; Taels et al., 2023), and constrain the activities autistic people take part in (Ismael et al., 2018). Moreover, reports link experiences of sensory distress to trauma (Kerns et al., 2022). Thus, it is hardly surprising that autistic sensory differences are related to quality of life (Scheerer et al., 2022). Furthermore, early differences in sensory reactivity and neural responsivity can predict later autism traits/diagnoses (Baranek et al., 2018; Kolesnik et al., 2019).

Clifford D. Saron and Susan M. Rivera co-senior authors.

✉ Patrick Dwyer
patrick.dwyer@latrobe.edu.au

1 Center for Mind and Brain, University of California, Davis, Davis, CA, USA

2 Department of Psychology, University of California, Davis, Davis, CA, USA

3 MIND Institute, UC Davis Health, Sacramento, CA, USA

4 Olga Tennison Autism Research Centre, School of Psychology and Public Health, La Trobe University, Bundoora, VIC, Australia

5 Laboratoire de Neurosciences Cognitives, Centre National de la Recherche Scientifique, Aix-Marseille University, Marseille, France

6 Sonova AG, Stäfa, Switzerland

7 Department of Psychology, University of Maryland, College Park, MD, USA

Published online: 24 June 2025

Sensory Phenotypes and Forms of Auditory Hyper-Reactivity

Despite their profound impacts, autistic sensory reactivity and sensory experiences remain poorly understood. Additional research using a wide variety of measures, and examining multiple constructs, is needed to enhance our understanding of how to conceptualise and measure autistic sensory experiences.

Much of the literature focuses on broad constructs such as sensory hyper-reactivity (being more strongly reactive to sensory stimuli, especially aversive stimuli), hypo-reactivity (being less reactive to sensory stimuli), and sensory interests (being interested in or fascinated by exploring sensory properties of things), but some of these broad patterns may be modality-specific (Williams et al., 2023). Hearing is particularly important; it is the modality in which autistic and other neurodivergent people report the most distressing sensory experiences (Wada et al., 2023; see also Strömberg et al., 2022). However, even within this auditory modality, hyper-reactivity alone does not appear to be unitary (Williams et al., 2021).

While there is debate regarding the conceptualization of, and terminology for, forms of auditory hyper-reactivity in autism and in the general population (Jastreboff & Jastreboff, 2015; Tyler et al., 2014; Williams et al., 2021), one important pattern is *misophonia*, which appears to be common in autism (Dwyer et al., 2023, 2025; Williams et al., 2022), though literature regarding misophonia in autism is currently limited. Misophonic reactions are emotional responses, especially anger and frustration, and disgust, caused by trigger sounds (Jager et al., 2020); these often-repetitive triggers can be seen as obnoxious and infuriating. Human-produced sounds such as chewing are particularly common and aversive triggers, but non-human sounds such as repetitive keyboard clicks can also trigger misophonia (Enzler et al., 2021b; Hansen et al., 2021). Misophonic reactions appear to be partly driven by participants' identification of a sound as a trigger sound, not just by stimulus properties (Heller & Smith, 2022; Savard et al., 2022). To elicit misophonic reactions, trigger sounds do not necessarily need to be perceived as loud (Enzler et al., 2021b; Swedo et al., 2022).

In contrast, the term *loudness hyperacusis* is often used to describe experiencing sounds of relatively moderate intensity as uncomfortably loud, when these sounds are usually not perceived as uncomfortably loud by others (Tyler et al., 2014; Williams et al., 2021). Thus, where misophonia need not involve perception of loudness, loudness hyperacusis inherently does. However, it may be difficult to clearly disentangle misophonia and hyperacusis from *sensory overload*: more general feelings of being overwhelmed by the intensity, diversity, or pattern of stimuli around oneself (Scheydt et al., 2017; Taels et al., 2023); "intensity" implies overlap with hyperacusis, while "pattern" could suggest overlap with misophonia. These experiences can be difficult to articulate using neurotypical language (Belek, 2018), but such experiences of overload are often described in autistic accounts of sensory reactivity (Belek, 2018; MacLennan et al., 2022; Strömberg et al., 2022). The experiences appear to be closely related to one's sense of control over one's environment (Taels et al., 2023) and they can lead to stress, disturbed thought processes (e.g., incoherent thinking), mood and behaviour changes, perceptual disturbances, and reduced attention (Scheydt et al., 2017). In turn, the idea of sensory overload appears to overlap with *noise sensitivity*, a concept sometimes used to describe heightened reactivity to sounds outside of loudness hyperacusis or other specific phenotypes (Williams et al., 2021), and which, in its own right, could potentially have a fuzzy boundary with the more specific sound aversions characteristic of misophonia.

Another sound intolerance construct is *phonophobia*, a specific phobia of certain sounds or types of sounds, resulting in anticipatory anxiety and avoidance (Williams et al., 2021); phonophobia is common in autism (Lau et al., 2020). Just as misophonic reactions can be separated from loudness/overload reactions, phonophobia might be distinguishable from more generalised sensory anxieties that are common among autistic people, such as fears of loud sounds (see Lau et al., 2020). The recent Multidimensional Inventory of Sound Tolerance-Adult (MIST-A), designed for use in autism, has a "fear/panic" dimension; however, items appear not to capture *anticipatory* anxiety, but rather panicked/distressed *reactions* to aversive sounds (Williams et al., 2023; see also Scheerer et al., 2022). While not the focus of this study, more research regarding measurement of phonophobia in autism may be needed.

Though some of these sound intolerance dimensions can be distinguished from one another, they may not be without common roots. Even outside autism, greater loudness discomfort appears to be related to misophonia symptoms (Aazh et al., 2022), and contributions of autistic traits to sound intolerance within autism might accentuate such relationships. This may be reflected in the more generalised, modality-independent idea of sensory overload.

And beyond sound intolerance, there is at least one other variety of auditory hyper-reactivity often observed in autism. Autistic people can sometimes be more aware than non-autistic people of background sounds or other stimuli; this increased awareness of background stimuli is not always distressing (Remington & Fairnie, 2017). Nevertheless, in some contexts, autistic people's increased awareness of such stimuli can lead to *auditory distractibility/filtering problems* and difficulties focusing on following conversations or

completing work (Dunlop et al., 2016; Dwyer et al., 2023, 2025; Scheerer et al., 2022; Taels et al., 2023).

Interestingly, some questionnaire-based sensory measures are intended to capture levels of sensory and perceptual acuity (e.g., Ausderau et al., 2014; Dunn, 1997; Tavassoli et al., 2016), and some measures or subscales have even been constructed in order to capture a sensory "threshold" for detection of or reaction towards stimuli (Dunn, 1997). However, questionnaire subscales intended to capture sensory/perceptual acuity do not appear to converge with psychophysical thresholds (Dwyer et al., 2022). It seems possible these questionnaires instead capture everyday sensory distractibility/filtering issues.

Lab-Based Sensory Ratings

Indeed, not only do existing questionnaires generally fail to distinguish among these auditory hyperreactivity phenotypes, but existing questionnaires– including ones intended to capture sensory/perceptual acuity– show limited convergence with other sensory measures, such as psychophysical detection/discrimination thresholds (Dwyer et al., 2022; Quinde-Zlibut et al., 2020). In autism sensory research, associations between supposedly-different constructs measured using comparable methods can be stronger than associations between supposedly-similar constructs measured using different methods (Wodka et al., 2016). Therefore, multi-method investigation of processes and experiences is an important direction for autism sensory research (Uljarević et al., 2017) and it is possible that using psychophysical techniques to explore the pleasantness and comfort of stimuli, rather than detection/discrimination, might result in greater convergence with questionnaires.

Autistic people, on average, report finding stimuli uncomfortably loud at lower intensity/volume levels than do non-autistic controls (Demopoulos & Lewine, 2016; Dunlop et al., 2016; Khalfa et al., 2004). Moreover, Dunlop and colleagues (2016) found that autistic participants who reported more discomfort to sound stimuli had higher scores on a sound discomfort questionnaire. However, prior autism studies have usually focused on ratings of a limited range of stimuli, such as pure tones (Khalfa et al., 2004) and speech sounds (Demopoulos & Lewine, 2016; Dunlop et al., 2016). Behavioural reactions to naturalistic sounds have been observed (McCormick et al., 2014; Siper et al., 2017; Tavassoli et al., 2016), but autistic people can experience internal overload and distress while appearing behaviourally underreactive (Grandin & Panek, 2014, pp. 81–84). Michel and colleagues (2023) recently examined ratings of a variety of naturalistic stimuli, finding that autistic people, unlike non-autistic controls, reported finding vocal sounds less pleasant than non-vocal sounds. Furthermore, given theories regarding endogenous neural noise in autism (e.g., Davis & Plaisted-Grant, 2015; Sohal & Rubenstein, 2019), the authors examined stimuli with varying harmonic-to-noise ratios (that is, different levels of exogenous noise relative to the main sound signal); while both autistic and non-autistic groups found stimulus pleasantness was enhanced by higher harmonic-to-noise ratios, this effect was reduced in autistic people. However, harmonic-to-noise ratios appear to have been confounded with sound types (and possibly additional dimensions, such as frequency). Moreover, studies outside of autism have gone farther, using ratings of naturalistic sounds to draw distinctions between different sound intolerance phenotypes. For example, non-autism studies have measured misophonic reactions using ratings of a variety of potential misophonia triggers (Enzler et al., 2021b; Hansen et al., 2021; Heller & Smith, 2022; Savard et al., 2022). Loudness distress, however, has its own profile; relative to controls, hyperacusic participants often rate conventionally-pleasant sounds, e.g., water flowing and birds chirping, as more aversive, presumably due to them being too loud (Enzler et al., 2021a). How autistic people would respond to such paradigms remains unclear.

Informant Discrepancies

Another measurement challenge concerns reliance on proxy reports. Most autism sensory studies, and even many studies of older children and adults, have not collected self-reports (Ben-Sasson et al., 2019). Non-autistic experts traditionally assumed that autistic people lack self-insight (Johnson et al., 2009), an ableist stereotype which contributed to the neglect of autistic people's perspectives. Only individuals have direct access to their sensory experiences, whereas behavioural reactions to stimuli can be misleading (Grandin & Panek, 2014, pp. 81–84).

Few sensory questionnaires used in the autism field have largely identical proxy- and self-report versions, making it difficult to evaluate convergence across raters. A handful of studies suggest that autistic and general population adolescents report more auditory sensory reactivity than their caregivers proxy-reported (Keith et al., 2019; Millington et al., 2021). Pain ratings do not differ across self- and caregiver-reports, but neither are autistic children's reports of pain associated with their caregivers' (Bandstra et al., 2012), and caregivers' reports might be influenced by their own mental health (Grosvenor et al., 2021). Adolescents' ratings of their auditory hyperreactivity, but not caregivers' ratings, have been found to significantly correlate with autonomic reactivity to noise exposure, providing preliminary evidence of convergent validity for self-reports, but not for caregiver-reports (Keith et al., 2019).

Present Study

In the present study, well-characterised samples of autistic and comparison adolescents completed a mixture of self-report questionnaire and lab-based sensory measures; their caregivers also completed sensory questionnaires. In particular, the present study measured hyperacusis and misophonia using multiple methods: not only questionnaires, but also lab-based psychoacoustic tasks inviting participants to report on the pleasantness and comfortability of pure tones, conventionally-pleasant sounds, conventionally-unpleasant sounds, and common misophonia triggers. In addition, participants' hearing thresholds were measured, and their caregivers reported on participants' real-world enhanced perception experiences. Furthermore, the present study's questionnaire battery included measures and subscales capturing broad information regarding other sensory experiences and behaviours, such as experiences of sensory fear/overload and experiences of auditory distractibility. Hypotheses included:

1. Autistic participants, relative to comparison participants, would exhibit more auditory discomfort and distractibility in self-report, caregiver-report, and lab-based psychoacoustic measures, but their hearing acuity would not differ.
2. Most measures intended to index the same sensory constructs (especially measures of hyperacusis and measures of misophonia) would converge, even if measurement methods (i.e., psychoacoustic tasks versus questionnaire-report) were different.
3. However, notwithstanding hypothesis 2, caregiver-reports of enhanced perception would not be associated with hearing acuity, and would instead converge with auditory distractibility and sound intolerance.
4. Measures of different sensory constructs would converge with one another (e.g., hyperacusis and misophonia measures would converge) when both use the same methods (e.g., when both are questionnaire-based, or both are lab-based discomfort ratings).
5. Caregiver- and self-reported auditory hyperreactivity scores would be associated with one another, but autistic participants would self-report more atypical and uncomfortable auditory sensory experiences, relative to caregiver proxy-reports.

Methods

This study is part of a larger project (including electrophysiology and attention tasks described by Dwyer et al., 2024). Participants completed three in-person visits with a total scheduled time commitment of six hours, and had the option to complete questionnaires at home or in the lab.

Participants

Participants aged 11–16 years old were recruited from community advertising via social media and community groups, personal contacts, an autism-focused institutional research registry (the UC Davis Mind Institute Research Participant Registry), and a general population research registry (the UC Davis Center for Mind and Brain's participant pool). This age range was chosen to maximise the degree to which both participants and caregivers would likely be available and able to provide such reports. Study advertising described the purpose as "studying how children on the autism spectrum experience sights and sounds, and how their brains respond to those experiences."

18 autistic and 22 control participants provided useable study data. As reported in Table 1, the autistic and comparison groups did not statistically differ in handedness or gender, although there were some trends for groups to differ in age and cognitive ability. Autistic participants had prior autism diagnoses. All autistic participants' diagnoses were confirmed by clinicians in evaluations including Autism Diagnostic Observation Schedule (ADOS)-2 (Lord et al., 2012) during the study or < 1 year previously. Comparison participants had no suspected neurodivergence and no 1st /2nd -degree autistic relatives. Participants in both groups had trichromatic vision and at least 20/40 (corrected) vision. In both groups, intellectual disability and hearing loss were exclusionary. Further details are provided in Appendix B.

Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II)

The WASI-II (Wechsler, 2011) is a brief, standardised cognitive ability measure. The block design and matrix reasoning subtests of an interchangeable assessment may more accurately measure cognitive ability in autism (Nader et al., 2016), so nonverbal cognitive ability composites based on them were used to control for any group differences in cognitive ability.

Sensory Questionnaires

Multidimensional Inventory of Sound Tolerance-Adult (MIST-A)

The Multidimensional Inventory of Sound Tolerance-Adult (MIST-A) is a self-report measure of decreased sound tolerance originally developed for adults, including autistic adults (Williams et al., 2023). 24 items measure frequency

Table 1 Continuous variables describing the present study sample. Continuous variables are compared across groups using uncorrected Wilcoxon-Mann-Whitney tests, with cliff's δ as an effect size. Categorical variables are compared using fisher's exact tests, with cramér's V as an effect size

	Autistic			Comparison			*p*	Effect [95% CI]
	M (SD)	Range	*n*	M (SD)	Range	*n*		
Age (years)	13.72 (1.64)	11.24 to 15.94	18	13.05 (1.50)	11.16 to 15.67	22	0.16	0.27 [–0.11, 0.58]
SCQ-Lifetime Total Autistic Traits	20.39 (6.32)	10 to 33	18	2.41 (1.92)	0 to 7	22	<0.0001****	1.00 [0.995, 1.00]
SWAN Inattention	0.52 (1.14)	–1.67 to 2.33	18	–0.97 (0.78)	–2.78 to 0.33	22	0.0002***	0.70 [0.37, 0.87]
SWAN Hyperactivity/ Impulsivity	0.69 (1.23)	–1.78 to 2.56	18	–0.97 (0.90)	–2.89 to 0.00	22	0.0001***	0.72 [0.37, 0.89]
ASC-ASD Caregiver-Report Total Anxiety	22.06 (10.27)	7 to 40	18	9.95 (5.69)	2 to 19	22	0.0002***	0.70 [0.39, 0.86]
ASC-ASD Self-Report Total Anxiety	17.83 (13.49)	4 to 59	18	13.24 (8.56)	2 to 30	21	0.34	0.18 [–0.19, 0.51]
Modified Edinburgh Handedness	46.95 (47.80)	–100.00 to 100.00	18	55.10 (31.59)	–26.32 to 100.00	21	0.58	–0.11 [–0.45, 0.27]
WASI-II Verbal Comprehension	111.33 (19.72)	80 to 149	18	122.50 (10.80)	102 to 144	22	0.06	–0.35 [–0.65, 0.05]
WASI-II Perceptual Reasoning	104.00 (14.93)	73 to 129	18	110.00 (12.59)	85 to 137	22	0.20	–0.24 [–0.56, 0.14]
WASI-II FSIQ-4	108.61 (17.62)	78 to 136	18	118.82 (10.37)	101 to 140	22	0.055	–0.36 [–0.65, 0.02]
Gender	3 female (16.67%) 14 male (77.78%) 1 nonbinary (5.56%)			6 female (27.27%) 16 male (72.73%)			0.46	0.21
Race/ ethnicity	9 non-Hispanic White (50.00%) 2 Hispanic/Latiné (11.11%) 3 Mixed (16.67%) 1 Filipino (5.57%) 1 Black (5.57%) 1 declined (5.57%, omitted in analysis)			15 non-Hispanic White (68.18%) 4 Hispanic/Latiné (18.18%) 2 Mixed (9.09%) 1 East Asian (4.55%)			0.59	0.35

of sound intolerance experiences, specifically misophonia (8 items), loudness hyperacusis (9 items), fear/panic (3 items), and pain hyperacusis (4 items). Bodily/physiological hyperacusis symptoms (8 items) and systemic nonspecific symptoms (7 items) are indexed. These items are rated from "Never (not in the past month)" (0) to "Very often (multiple times per day)" (4); higher scores reflect greater sound intolerance. Finally, 8 Likert items regarding daily-life impacts of diminished sound tolerance, rated from "Not at all" (0) to "Very much" (4), measure impairment/impacts on quality of life. 9 items are used for screening; if participants report none of the screened sound intolerance experiences, scores are assumed to be zero.

Vanderbilt Auditory Distractibility Questionnaire (VADQ)

The Vanderbilt Auditory Distractibility Questionnaire (VADQ) is a brief, 7-item, unidimensional self-report measure of auditory distractibility originally developed for use with autistic adults (Williams, 2021). Items are rated from "Strongly Disagree" (0), reflecting minimal auditory distractibility, to "Strongly Agree" (5), indicating greater distractibility.

Duke-Vanderbilt Misophonia Screening Questionnaire (DVMSQ)

The Duke-Vanderbilt Misophonia Screening Questionnaire (DVMSQ) (Williams et al., 2022) is a self-report measure validated in general-population and autistic adult samples (Williams et al., 2022). If participants report being bothered by specific sounds, even if they are not loud, participants complete the measure; otherwise, scores are assumed to be zero. 17 items generate total scores; higher scores reflect higher levels of misophonia. Symptoms/experiences of "Anger and Aggression" (4 items) and "Distress and Avoidance" (5 items, including one cross-loading on "Anger and Aggression") are measured along with impacts/impairment (7 items). In this study, references to jobs were omitted.

Brain-Body Center Sensory Scales (BBCSS)

The 50-item brief self- and proxy-report forms of the Brain Body Center Sensory Scales (BBCSS) (Kolacz et al., 2018) measure Auditory Hypersensitivity (9 items), Auditory Hyposensitivity to Voices (5 items), Visual Hypersensitivity (10 items), Tactile Hypersensitivity (10 items), Affiliative Touch Aversion (3 items), Selective Eating (6 items), Ingestive Problems (3 items), and Digestive Problems (4 items). Response options range from "Almost Never" (1) to "Almost Always" (4), with higher scores meaning more of a given sensory difference; a "Not Sure/Not Applicable" option is ignored when scores are calculated. Due to this not applicable option, the number of participants with useable BBCSS data varies from subscale to subscale (see Supplementary Tables A.16-A.17).

Sensory Experiences Questionnaire, Version 3.0 (SEQ-3.0)

The SEQ-3.0 is a 105-item caregiver-report sensory behaviour questionnaire (Ausderau et al., 2014) with items scored from "Never/Almost Never" (1) to "Almost Always/Always" (5), with higher scores meaning higher levels of a sensory behaviour pattern. It assesses hyporesponsiveness (HYPO), hyperresponsiveness (HYPER), sensory interests and seeking (SIRS), and enhanced perception (EP)– with EP being defined as "superior acuity in the awareness of specific sensory stimuli" (Ausderau et al., 2014). However, SEQ EP does not converge with psychophysical thresholds (Dwyer et al., 2022), and some EP items were classified by Williams et al. (2023) as HYPER items. The SEQ collects data from five modalities– auditory, visual, tactile, gustatory/olfactory, and vestibular/proprioceptive– and as the interpretability of modality-independent sensory pattern scores from the SEQ has been challenged (Williams et al., 2023), this study used modality-specific scores.

Other Questionnaires

Several questionnaires were collected to characterise neurodivergent traits and anxiety in this study's sample.

Social Communication Questionnaire (SCQ)– Lifetime Form

The lifetime version of the Social Communication Questionnaire (SCQ) is a 40-item, yes/no parent-report measure of autistic characteristics, with a particular retrospective focus on ages 4–5. Higher scores reflect greater autistic characteristics; scores over 15 are considered indicative of autism (Berument et al., 1999).

Strengths and Weaknesses of ADHD-symptoms and Normal-behavior (SWAN)

The SWAN is an 18-item questionnaire inviting caregivers to rate their child's attention (9 items) and hyperactivity/impulsivity (9 items) on a 7-point scale from "Far Below Average" (3) to "Far Above Average" (-3); higher scores reflect more ADHD traits (Swanson et al., 2012).

Anxiety Scale for Children with Autism Spectrum Disorder (ASC-ASD)

Both caregiver- and self-report versions of the 24-item ASC-ASD (Rodgers et al., 2016) were collected. Items are scored from 0 ("Never") to 3 ("Always"); higher scores reflect greater anxiety. Subscales include Anxious Arousal (6 items), Performance Anxiety (5 items), Separation Anxiety (5 items), and Uncertainty (8 items). Caregiver-report data were available from all participants, but one self-report participant did not complete the ASC-ASD.

Psychoacoustic Tasks

All psychoacoustic tasks were presented in an audiometrically quiet, non-acoustically reflective chamber, using pneumatic airbag suspension system to suppress external vibrations. An experimenter was seated with participants; this experimenter used earbuds to communicate with the other experimenter(s), who monitored the chamber via video and microphone. Additional details regarding the tasks are included in Appendices C-E.

Hearing Thresholds

Hearing thresholds were measured in each ear with an Otovation Amplitude T4 audiometer and Sennheiser HDA-200 audiometric headphones. Participants were told to "press the button when you hear a tone, even if it was really soft or you just thought you may have heard a tone" (see Appendix C). Participants then listened to 1000 ms pure tones of 125, 250, 500, 1000, 2000, 4000, and 8000 Hz, with random interstimulus intervals between 1200 and 2500 ms. Starting intensity was 40 dB HL, and levels increased in steps of 5 dB or decreased in steps of 10 dB via a Hughson-Westlake procedure, until the participant's threshold, or −10 dB HL, was reached. Lower thresholds reflect greater acuity.

Loudness Discomfort Levels (LDLs)

Loudness discomfort was measured binaurally (in both ears together) with the Otovation Amplitude T4 system. Instructions were adapted from the British Society of Audiology recommendations (2011) (Appendix D). Participants then listened to 1000 ms pure tones of 250, 1000, 4000, and 8000 Hz, presented manually by the experimenters with brief gaps between each tone. The initial intensity was 45 dB HL, increased in 5 dB steps until participants indicated discomfort, or until the maximum intensity was reached (95 dB HL @ 250 Hz, 105 dB HL @ 1000 Hz, 95 dB HL @ 4000 Hz, 90 dB HL @ 8000 Hz). Intensity was then decreased by 20 dB before resumption of 5 dB increases, until participants had indicated discomfort or reached the maximum intensity three times. Discomfort levels were the average of these three intensities, unless the participant was already uncomfortable at 45 dB HL, in which case only lower-intensity runs were used (this occurred for three participants, at 4000 and/or 8000 Hz). Lower discomfort levels would suggest greater susceptibility to hyperacusis.

Core Discriminant Sounds (CDS)

A full description of the Core Discriminant Sounds (CDS) task is presented in Appendix E, but briefly, it can measure both misophonia (Enzler et al., 2021a) and hyperacusis (Enzler et al., 2021b). Participants rate sounds on a visual analogue scale (VAS) from "pleasant" (0) to "unpleasant" (100). Participants were told that "maximally unpleasant ratings should mean a sound is unbearable." Sounds are repeated twice at increasing intensities: 50 dB, 60 dB, 70 dB, and 80 dB SPL. If participants strongly disliked a sound (VAS ratings ≥ 90), that sound was not presented again. Participants listened to 7 conventionally-pleasant sounds (e.g., birds, fountain); 10 misophonia triggers, including breathing/nasal sounds, mouth sounds, throat sounds, and repetitive sounds; and 6 conventionally-unpleasant sounds (e.g., fingernails on chalkboard, scream) (see Enzler et al., 2021a; Enzler et al., 2021b).

The logic of this task is to compare participant's responses to a control population (here, non-autistic, non-hyperacusis, non-misophonic participants). The core discriminant sounds (CDSs) are those optimally differentiating the two populations (Enzler et al., 2021a; Enzler et al., 2021b). Rating misophonic trigger sounds as more unpleasant suggests more misophonic reactions towards those sounds, as one would expect. For hyperacusis, surprisingly, the CDSs are pleasant sounds rather than unpleasant sounds. Presumably, people experiencing hyperacusis have a less pleasant experience of typically-pleasant sounds when they are presented at sufficient intensity, because of the aversion to loudness inherent in hyperacusis.

CDS scores were calculated for misophonia (CDS_{Miso}) and hyperacusis (CDS_{HypA}) based, on the degree to which a participant's response exceeded the 75% quantile of controls' ratings of misophonic trigger sounds (CDS_{Miso}) and conventionally pleasant sounds (CDS_{HypA}). Scores range from 0 (meaning ratings equal or less than the 75% quantile of controls) to 100 (meaning maximally unpleasant ratings). 75% quantiles are presented in Supplementary Table A.3.

Analyses

Group Differences on Psychoacoustic Tasks

Hearing thresholds for each frequency and ear, LDLs at each frequency, and CDS scores at all intensities were compared across diagnostic groups using ordinal probit regression (Harrell, 2022; Ripley et al., 2022) in R (R Core Team, 2022), controlling for age and WASI Perceptual Reasoning standard scores.

Associations among Sensory Measures

Associations among auditory hyper-reactivity measures were examined using scaled, ranked regression in R, covarying for diagnostic group: this effectively yields a Spearman's correlation controlling for any group differences. Of particular interest in the present study was convergence of measures of misophonia (DVMSQ scores, MIST-A misophonia, and CDS_{Miso} scores) and hyperacusis (MIST-A loudness, pain, and hyperacusis symptom scores, CDS_{HypA}, and LDLs); but other forms of auditory hyper-reactivity were also included in the analyses.

Separately, analyses examined whether SEQ auditory enhanced perception scores were associated with Pure Tone Average (PTA) hearing thresholds, or conversely whether they showed more robust associations with measures of sound intolerance/distractibility.

Full association matrices involving additional variables are presented in Appendix A.

Auditory Hyper-Reactivity Group Differences

For subsequent group difference analyses, when measures purportedly indexing the same sensory constructs (e.g., misophonia), were sufficiently associated– reflected by statistically significant (before any multiple comparison correction) scaled, ranked regression coefficients of 0.4 or greater,[1] controlling for diagnostic group– composites were created, analogously to the approach of Feldman and colleagues (2021). In R, raw scores on the variables were converted to scaled *z*-scores and averaged. The resulting composites, and other auditory sensory measures, were compared across diagnostic groups using Wilcoxon-Mann-Whitney tests, with Cliff's δ as an effect size. Group comparisons of all other sensory measures are presented in Appendix A.

[1] The inferential *p*-values from the scaled, ranked regression analyses remain the same regardless of which variable is the predictor. However, coefficients vary depending upon which variable is entered into the regression model as the predictor and as the response (see Supplementary Table A.4). The average of these two coefficients was used to determine whether the variables were sufficiently associated for the creation of composites.

Caregiver-Child Reporter Differences

Finally, to compare parent- and child-reports of sensory phenotypes, BBCSS auditory hyperreactivity subscale scores were entered into a cumulative link multilevel model using the ordinal package (Christensen, 2022) in R, controlling for age and nonverbal cognitive ability with *r* as an effect size (Kassambara, 2022) for follow-up Wilcoxon paired tests.

Results

Group Differences on Psychoacoustic Tasks

As expected, groups did not statistically differ in hearing thresholds averaged across ears, $b = 0.52$, $p = .13$,, 95% CI=[−0.15, 1.20], nor did they differ in hearing thresholds at any frequency in either ear (Supplementary Table A.1; *Supplementary Figure A.1*).

Unexpectedly, there were also no statistical between-group differences in loudness discomfort levels (LDLs), either on average, $b = 0.37$, $p = .29$, 95% CI=[−0.31, 1.05], or for any frequencies examined (Supplementary Table A.2), although visual inspection suggested a subset of autistic participants strongly disliked high-frequency sounds (Supplementary Figure A.2).

Also unexpectedly, CDS_{Miso} scores did not statistically differ between diagnostic groups, despite some apparent trends at 60 and 80 dB (Table 2; *Supplementary Figure A.3*; see also raw sound ratings in *Supplementary Figure A.4* and scores for each trigger type in Supplementary Table A.13). However, groups did differ in CDS_{HypA} scores, reflecting greater aversion to 60, 70, and 80 dB conventionally-pleasant naturalistic sounds in autistic participants (Table 2; *Supplementary Figures A.3-A.4*). The effect of group on CDS_{HypA} scores to 50 dB sounds did not approach significance, suggesting 50 dB was too soft for most autistic participants to experience an unusually negative reaction. Participants' median ratings of each conventionally-pleasant sound, collapsed across intensities, are compared across groups in Supplementary Table A.14; only ratings of fountain and ocean (but not underwater) sounds significantly differed between groups, and only before correction, but autistic participants on average always gave somewhat more unpleasant raw ratings to the sounds, contributing to the CDS_{HypA} effect. Ratings of conventionally-unpleasant sounds appeared similar across groups (Supplementary Figure A.5, Supplementary Table A.12).

Table 2 Results of ordinal probit regressions tests comparing autistic and non-autistic comparison participants' core discriminant sound (CDS) scores for hyperacusis and for misophonia, controlling for age and nonverbal cognitive ability, separately at each intensity level, as well as on average. A false discovery rate correction for 10 comparisons was applied

	CDS Misophonia					CDS Hyperacusis				
	50 dB	60 dB	70 dB	80 dB	Average	50 dB	60 dB	70 dB	80 dB	Average
Autistic Mean (SD)	12.30 (22.51)	20.19 (28.65)	28.30 (39.96)	38.13 (40.03)	21.72 (27.55)	8.87 (11.75)	14.03 (16.81)	27.48 (30.26)	33.57 (37.75)	20.52 (20.67)
Comparison Mean (SD)	11.80 (17.64)	14.92 (24.30)	15.05 (25.16)	21.49 (31.94)	14.40 (20.76)	3.53 (5.18)	3.77 (5.90)	7.06 (10.81)	10.50 (17.64)	6.06 (8.22)
p_{raw}	0.69	0.08	0.16	0.059	0.17	0.21	0.01*	0.01*	0.005**	0.006**
p_{cor}	0.69	0.14	0.21	0.12	0.21	0.23	0.03*	0.03*	0.03*	0.03*
b	−0.14	−0.63	−0.55	−0.72	−0.48	−0.44	−0.88	−0.89	−1.03	−0.99
[95% CI]	[−0.85, 0.57]	[−1.35, 0.08]	[−1.33, 0.22]	[−1.47, 0.02]	[−1.17, 0.20]	[−1.12, 0.25]	[−1.57, −0.19]	[−1.60, −0.18]	[−1.75, −0.31]	[−1.69, −0.29]

Auditory Hyper-Reactivity Associations

Within-Construct Associations: Misophonia

Different measures of misophonia clearly converged, even when these measures used different methods (Supplementary Tables A.4-A.7, *Supplementary Figure A.6*). Indeed, the association between self-report questionnaire-based DVMSQ and laboratory-based CDS_{Miso} scores, p_{raw}=0.007, p_{cor}=0.02, was comparable to that between DVMSQ and likewise-questionnaire-based MIST-A misophonia scores, p_{raw}=0.001, p_{cor}=0.01. The association between MIST-A misophonia and CDS_{Miso} scores did not approach significance, p_{raw}=0.12, p_{cor}=0.20, although a trend was observed in autistic participants alone, p_{raw}=0.04, p_{cor}=0.15 (Supplementary Table A.6).

Within-Construct Associations: Hyperacusis

Self-report questionnaire-based MIST-A hyperacusis symptom scores and MIST-A loudness hyperacusis experience scores were associated, p_{raw}=0.002, p_{cor}=0.01, as were MIST-A hyperacusis symptom and pain hyperacusis experience scores, p_{raw}=0.001, p_{cor}=0.01, as were MIST-A pain and loudness hyperacusis experience scores, p_{raw}=0.0001, p_{cor}=0.002 (Supplementary Tables A.4-A.7, *Supplementary Figure A.7*). Similarly, laboratory rating-based CDS_{HypA} scores and average loudness discomfort levels (LDLs) trended towards being associated, p_{raw}=0.02, p_{cor}=0.06. But contrary to this study's hypothesis, scores from self-report questionnaire and laboratory-based hyperacusis measures were not related, $p_{raw}\geq0.56$, $p_{cor}\geq0.68$.

Other Auditory Hyper-Reactivity Associations

As expected, self-report MIST-A scores from various subscales tended to converge with one another (Supplementary Tables A.4-A.7); a number of these self-report subscores also tended to converge with self-report VADQ auditory distractibility scores and BBCSS auditory hypersensitivity scores. There were also some associations with self-report DVMSQ scores.

However, there were no statistically robust relationships between psychoacoustic sound comfort/pleasantness ratings and self-report MIST-A or BBCSS auditory hyperreactivity scores.

Similarly, as expected, different psychoacoustic scores converged with one another across constructs: CDS_{HypA} and CDS_{Miso} scores were robustly related, p_{raw}=0.0001, p_{cor}=0.002, and CDS_{Miso} scores tended to converge with loudness discomfort levels, p_{raw}=0.03, p_{cor}=0.08.

Caregiver-report SEQ and BBCSS auditory hyper-responsiveness/sensitivity scores were strongly related, p_{raw}<0.0001, p_{cor}<0.0001, but these caregiver-report subscores seldom converged with self-report scores. SEQ auditory hyper-responsiveness was only robustly associated with MIST-A fear/panic scores and nonspecific symptom scores, while BBCSS caregiver-report hyper-sensitivity was only robustly associated with its BBCSS self-report equivalent.

Complete association matrices are presented in Supplementary Table A.8.

Auditory Enhanced Perception Associations

Unexpectedly, SEQ Auditory EP scores were not related to hearing thresholds *or* sound intolerance/distractibility, even before *p*-value correction (Supplementary Tables A.9-A.11). Instead, exploratory analyses found that auditory EP was predicted by SEQ Auditory Interests, Repetitions, and Seeking (SIRS), β = 0.74, p_{raw}<0.0001, p_{cor}=0.0002 (Supplementary Table A.8). This effect could be observed in both the autistic, Spearman's ρ = 0.70, 95% CI=[0.35, 0.88], p_{raw}=0.001, and comparison, ρ = 0.52, 95% CI=[0.12, 0.77], p_{raw} =0.01, groups.

Auditory Hyper-Reactivity Group Differences

For analyses of group differences in auditory hyper-reactivity phenotypes, following procedures described in the "Analyses" section, composite scores were created for misophonia (from DVMSQ and CDS_{Miso}), self-reported hyperacusis (MIST-A loudness and pain hyperacusis and hyperacusis symptoms), and caregiver-report auditory hyperreactivity (caregiver-report SEQ and BBCSS auditory hyperresponsiveness/hypersensitivity).

Autistic participants experienced more misophonia, hyperacusis, auditory fears/panic, auditory enhanced perception, auditory distractibility, generalised auditory hyperreactivity reactivity, and impairment/quality of life impacts from sound intolerance, all corrected $p \leq .04$ (Table 3). Groups did not significantly differ in nonspecific auditory symptoms, $p = .22$ (Table 3).

Group differences on all sensory measures examined in this study can be found in Supplementary Table A.12. Notably, the composite misophonia group differences in Table 3 appeared to be driven by self-reports rather than ratings of sounds presented in the laboratory. We were curious whether this might reflect the types of triggers identified by participants, and indeed, autistic participants' DVMSQ responses mentioned some triggers that were not presented in the CDS task (Supplementary Table A.15). Interestingly, some of these triggers– such as singing (mentioned by two autistic participants)– might conventionally be considered pleasant.

Although analyses in Table 3 use a composite measure of self-reported hyperacusis, group differences appeared to be driven by loudness hyperacusis; group differences in pain hyperacusis and bodily symptoms did not reach significance (Supplementary Table A.15).

Caregiver-Child Reporter Differences

As reported above (Supplementary Tables A.4-A.7), caregiver- and self-reports of auditory hyperreactivity were moderately and significantly associated.

Autistic participants generally experienced more auditory hyperreactivity than controls, $\chi^2 = 30.46$, p_{raw}<0.0001, p_{cor}<0.0001 (Supplementary Table A.16). There was also a significant effect of the age covariate, $\chi^2 = 3.94$, $p = .047$, and at a trend level of nonverbal cognitive ability, $\chi^2 = 3.26$, $p = .07$; Spearman's correlations suggested the effect of age may have reflected less caregiver-reported auditory hyperreactivity in older autistic participants, ρ=–0.53, $p = .02$. There was no main effect of reporter (caregiver- vs. self-), $\chi^2 = 0.18$, p_{raw}=0.68, but there was an interaction between reporter and diagnostic group, $\chi^2 = 7.60$, p_{raw}=0.006, p_{cor}=0.009. Unexpectedly, Wilcoxon paired tests suggested autistic participants usually self-reported *less* auditory hyperreactivity than their caregivers reported for them, $r = .59$, 95% CI=[0.22, 0.84], p_{raw}=0.01, p_{cor}=0.04, while control participants' self- and caregiver-reports did not significantly differ, $r = .28$, 95% CI=[0.02, 0.65], p_{raw}=0.21.

As an additional exploratory analysis, scores from other BBCSS subscales were examined (Supplementary Table A.16). Autistic participants similarly self-reported *less* atypical sensory phenotypes than reflected by their caregivers' proxy-reports on a number of subscales; furthermore, typically-developing participants sometimes self-reported *more* sensory issues than caregivers proxy-reported for them. Convergence between raters was generally poor.

Because BBCSS items can be left blank, sensitivity analyses were conducted on participants with more complete data (Supplementary Table A.17). Patterns of results were overall very similar to the main analyses reported here and in Supplementary Table A.16.

Discussion

The present study characterised auditory sensory phenotypes in autistic and non-autistic adolescents using a mixture of psychoacoustic tasks and caregiver-report/self-report measures.

Table 3 Results of ordinal probit regression models comparing autistic and non-autistic comparison participants' auditory sensory hyper-reactivity phenotypes, controlling for nonverbal cognitive ability and age. A false discovery rate correction for 11 comparisons was applied

	Autistic			Comparison			*p*	Coefficient [95% CI]
	M (SD)	Range	*n*	M (SD)	Range	*n*		
Misophonia Composite	0.29 (1.04)	-0.68 to 2.93	18	-0.24 (0.56)	-0.68 to 0.96	22	0.02* 0.03*	-0.81 [-1.51, -0.11]
MIST-A Misophonia	0.67 (0.70)	0.00 to 2.38	18	0.35 (0.31)	0.00 to 1.00	22	0.10 0.12	-0.57 [-1.25, 0.12]
Hyperacusis Self-Report Composite	0.40 (0.83)	-0.91 to 1.95	18	-0.33 (0.52)	-0.91 to 0.93	22	0.009** 0.02*	-0.92 [-1.62, -0.23]
MIST-A Fear/ Panic	0.96 (0.68)	0.00 to 2.33	18	0.52 (0.50)	0.00 to 1.67	22	0.01* 0.02*	-0.90 [-1.59, -0.20]
MIST-A Nonspecific Systemic Symptom	0.48 (0.59)	0.00 to 1.86	18	0.16 (0.24)	0.00 to 1.00	22	0.22 0.22	-0.46 [-1.18, 0.27]
MIST-A Impairment/ Quality of Life Impact	0.41 (0.46)	0.00 to 1.50	18	0.13 (0.25)	0.00 to 1.00	22	0.02* 0.03*	-0.88 [-1.60, -0.16]
VADQ Auditory Distractibility	2.40 (1.12)	0.57 to 4.29	18	1.65 (0.90)	0.00 to 3.29	22	0.03* 0.04*	-0.73 [-1.41, -0.06]
BBCSS Auditory HYPER Self-Report	1.98 (0.53)	1.00 to 2.88	18	1.41 (0.44)	1.00 to 2.89	21	0.002** 0.008**	-1.13 [-1.87, -0.40]
Auditory HYPER Caregiver Composite	0.76 (0.92)	-0.61 to 2.41	18	-0.64 (0.34)	-0.93 to 0.03	20	<0.0001**** <0.0001****	-2.91 [-3.96, -1.91]
SEQ Auditory Enhanced Perception	2.43 (0.98)	1.00 to 5.00	18	1.59 (0.60)	1.00 to 3.25	22	0.0007*** 0.004**	-1.24 [-1.96, -0.52]

Group Differences

As expected, autistic participants did not differ from comparison participants in hearing acuity, but overall, they reportedly exhibited generalised auditory hyper-reactivity and sound intolerance-related impairment/quality of life impacts, as well as auditory fear/panic. Moreover, as predicted, autistic participants appear to have experienced more misophonia and auditory distractibility, consistent with prior research (Dwyer et al., 2023, 2025; Scheerer et al., 2022; Williams et al., 2022), although group differences in misophonia were not statistically significant when relying on ratings of misophonic triggers presented in the laboratory. In supplementary analyses, groups did not appear to differ in median laboratory ratings of conventionally-unpleasant sounds either, likely reflecting ceiling effects due to highly negative ratings of the sounds in each group.

Instead, in laboratory visits, autistic participants generally gave unusually negative ratings to conventionally-pleasant sounds at intensities of 60 dB SPL (a normal conversational volume) or higher, a pattern which would canonically be interpreted as suggestive of elevated susceptibility towards hyperacusis and loudness discomfort– and indeed, autistic participants did self-report more hyperacusis, particularly loudness hyperacusis. However, as autistic and control participants did not apparently differ in loudness discomfort towards pure tones, at least at lower frequencies, some caution should be exercised in assuming that loudness/volume alone drove the auditory discomfort experienced by most participants in the autism group. Rather, autistic participants may often have had negative reactions towards some specific sounds that are not typically misophonia triggers, including some conventionally-pleasant sounds, perhaps finding them distressing and overwhelming, or at least somewhat aversive, when presented at sufficient volumes. Although in this study median ratings of only two of the conventionally-pleasant sounds significantly differed between autistic and nonautistic participants (Supplementary Table A.14), and then only before correction, this may reflect this study's small sample.

However, complicating misophonia measurement, as noted in Supplementary Table A.3, in this younger sample, non-autistic children rated mouth sounds extremely negatively at all intensities, largely preventing them from being used to compute CDS_{Miso} scores. This might reflect greater emotional reactivity in children. Future studies should consider presenting sounds at even softer RMS intensities, such as 40 dB. It is possible that the visual analogue response scale– ranging as it did from pleasant to unpleasant with no other labelled points– may have been interpreted differently by different participants, which would increase random variability.

Meanwhile, self-reports of elevated loudness hyperacusis in the autistic group could conceivably capture other reactions not necessarily specifically caused by sound volume. Experiences of loudness distress in the real world might take place in complex environments, with many overlapping stimuli. Thus, self-reported loudness distress in questionnaires might have been difficult to disentangle from generalised sensory overload and reactivity.

Thus, from the present study's results, it is not entirely clear whether autistic participant's unusually negative reactions to some conventionally-pleasant sounds may have involved mechanisms similar to or distinct from misophonia. A further issue may be the question of what misophonia is– various models have been put forward to explain misophonic reactions. Most straightforwardly, certain types of sounds (e.g., repetitive) may trigger emotional reactions in some people, though the properties eliciting such reactions have not been systematically mapped. Alternatively, some suggest misophonic aversions are driven more by motor movements and imagery (Kumar et al., 2021), though this account struggles to explain why misophonic triggers include non-motor sounds (Hansen et al., 2021). A new theory suggests misophonia can be understood as a reaction to violation of social politeness norms (Norena, 2024); if so, insofar as autistic people can be more resistant to conformity and arbitrary authority (Späth & Jongsma, 2019; Yafai et al., 2014) but can also show greater desire to punish harmless norm violations (Dempsey et al., 2022)– a seeming contradiction potentially reflecting developmental change, heterogeneity, or context– it is unclear how this might apply to autism. Studies considering cross-cultural social norm diversity, different trigger types, and systematic manipulation of sound properties may be best suited to investigate these possibilities within and outside autism.

Notwithstanding these questions, the complexity of the sound intolerance observed in the autistic group emphasises the importance of validating and accommodating autistic experiences of sound intolerance. It may also suggest that laboratory rating-based misophonia measures in autism or adolescents could require more trigger sounds and/or clearer response scales.

Associations among Measures

Exploration of the relationships among auditory reactivity measures suggested several informal "clusters" of measures that were often related to one another but less often related to measures from other "clusters." First, laboratory-based psychoacoustic discomfort indices– that is, Core Discriminant Sound misophonia (CDS_{Miso}) and hyperacusis (CDS_{HypA}) scores and, at least before correction for multiple comparisons, loudness discomfort levels (LDLs)– appeared to be

related to one another. They did not appear to converge with questionnaires, except that CDS_{Miso} scores were associated with those from the DVMSQ misophonia measure. Second, self-reported scores from the MIST-A sound intolerance questionnaire, the VADQ auditory distractibility measure, and the BBCSS auditory hyper-reactivity subscale tended to converge with one another, and to some extent with DVMSQ scores. Third, caregiver-reported auditory hyper-reactivity from the SEQ and BBCSS tended to relate to one another, and to some extent they also converged with self-report questionnaire measures, but not with psychoacoustic scores. Finally, contrary to expectations, auditory enhanced perception did not statistically associate with auditory hyper-reactivity and distractibility measures, but exploratory analyses suggested a robust relationship between auditory enhanced perception and sensory interests/seeking.

This was partly consistent and partly inconsistent with the study hypotheses. In general, common methods were expected to result in convergence between measures (e.g., self-report sensory questionnaires would converge with one another), as were shared constructs (e.g., misophonia measures would converge with one another). Most self-report, caregiver-report, and psychoacoustic discomfort measures did indeed tend to converge with other measures using the same methods, but measures putatively capturing the same constructs using different methods seldom converged. An exception was the DVMSQ, which did converge the CDS_{Miso}, suggesting that emotional misophonic reactions in autism are a relatively coherent construct. This may further imply that the DVMSQ's precise instructions and specific focus on misophonia experiences makes it more comparable to the specific context of a laboratory task. Alternatively, participants generally filled out questionnaires during or soon after the psychoacoustic task lab visit, and DVMSQ responses could have been influenced by memories of the CDS.

Unexpectedly, self-report and psychoacoustic measures of hyperacusis failed to converge with one another, despite being intended to capture aspects of the same construct. However, there are several reasons to be cautious about drawing overly strong conclusions from this null effect. For one, the present study's autism group was small, leading to a risk of Type II error. For another, it is possible that a dedicated, hyperacusis-specific questionnaire would have converged more with psychoacoustic task responses than relevant MIST-A scores.

Alternatively, hyperacusis might be difficult to disentangle from other forms of auditory discomfort, such as misophonia and sensory overload. This possibility could be consistent with the observation that the autistic group's reduced liking of moderately-loud, conventionally-pleasant sounds did not appear to be accompanied by overall aversion to loudness in pure tones. Conceivably, some conventionally-pleasant sounds might have been idiosyncratically disliked, perhaps consistent with the wide range of misophonia triggers reported by autistic participants in Supplementary Table A.15, leading to misophonia-like reactions being captured in the ratings of the conventionally-pleasant sounds. It is also possible that autistic people may have tended to find a wide range of sounds mildly less pleasant, perhaps reflecting sensitivity to subtle stimulus features, or perhaps skepticism of sounds related to past experiences of auditory discomfort.

As for auditory enhanced perception (EP), although the association between EP and sensory interests/seeking was unexpected, it may reflect the SEQ's item content. Auditory EP on the SEQ is indexed by four items, and while one (e.g., "How often does your child notice sounds in the environment…before other people do?") appears to reflect EP of background stimuli, others require the individual to generate sounds (e.g., "How often does your child have the exceptional ability to copy environmental sounds…"). In practice, children might often engage in sonic imitation as a way of further exploring interesting stimuli, which could be a form of sensory seeking, raising questions about the validity of EP as measured by the SEQ. While sonic imitation is also a coping strategy used by many people with misophonia (Ash et al., 2023), perhaps to provide a sense of control over the triggering stimulation, it is not clear that the SEQ's auditory EP items refer to aversive sounds, and SEQ auditory EP did not appear to be associated with misophonia.

Reporter Differences

In this study, autistic children were expected to self-report greater auditory hyperreactivity than indicated by their caregivers' proxy-reports. However, this pattern was not observed. On the contrary, for auditory hyperreactivity and several other forms of sensory experience, autistic participants' caregivers reported more atypical sensory processing than was indicated by participants' self-reports. Moreover, this was the opposite of the pattern observed in the comparison group, where for some forms of sensory experience examined in the supplementary materials, comparison participants self-reported more sensory discomfort and issues than suggested from their caregivers' proxy-reports.

There are many possible interpretations of autistic participants' caregivers' tendency to report higher levels of sensory processing differences. First, autistic participants may have struggled to understand and self-report their internal experiences, perhaps due to interoception difficulties (Trevisan et al., 2021). In this interpretation, despite lacking direct access to autistic participants' experiences, caregivers

may have been better able to interpret the observations they made.

Second, caregivers' responses may have been influenced by behaviours occurring when participants were younger. Although the BBCSS is worded in the present tense, the version in this study contained no explicit directions to base responses on a particular timeframe.

Third, caregivers might be more experienced advocates: as autistic adolescents often have limited involvement in advocacy activities such as school and transition planning meetings (Wagner et al., 2012), they may not be practiced at articulating autism-related differences.

Fourth, there could be a reference effect, whereby autistic and comparison participants' interpretations of the response options may have been influenced by their own experiences. For example, autistic participants might rate an experience as occurring merely "sometimes" when a comparison participant might rate it as occurring "often," due to autistic participants dismissing atypical sensory experiences as commonplace.

Finally, as this study did not explore identity or internalised stigma, one cannot exclude the possibility that autistic participants' answers might have been implicitly influenced by a desire to minimise differences between them and neurotypical children, while caregivers' roles in providing support might conceivably have had an opposite impact on their perspectives.

The present study's sample appears quite similar in age, cognitive ability, and gender to the sample from Keith et al. (2019)'s study of self- and caregiver-reports on the BBCSS, and Keith and colleagues found autistic participants self-reported more auditory sensory hyperreactivity than indicated by parents' proxy-reports. It is unclear what factors might have caused the difference between the outcomes of the two studies.

Limitations and Future Directions

Although the present study has the advantages of a rigorous, comprehensive battery of sensory measures and other sample characterization measures, its sample size is limited, due to the large amount of data collected from each participant (including attention tasks not reported in this manuscript). This prohibits examination of heterogeneity in sensory phenotypes, and readers should bear in mind that individual autistic people's auditory hyperreactivity profiles are likely to diverge from the average/medial patterns described here. It also means that the study's statistical power to detect associations is limited, so there is a risk of Type II error.

In addition, the present study uses some measures that are not validated for children and adolescents. When the study was designed, measures of specific sensory phenotypes such as misophonia were primarily designed and validated for use by adults. However, participants appeared to understand task instructions without a great deal of difficulty. The coherent patterns of results obtained in the CDS task suggests it can be used in further research with autistic and adolescent populations, but future studies should modify stimuli and response options to reduce ceiling effects and ensure scale clarity. Future research should also determine whether elevated CDS_{HypA} scores reflect hyperacusis or another pattern of sound intolerance, like idiosyncratic disliking of sounds. The CDS will only be clinically usable with autistic adolescents after this additional research has validated it and generated suitable norms for that population. In the meantime, expert practitioners may find interviews a useful component of evaluations (Siepsiak et al., 2023), as interviews may provide more context than is offered by psychoacoustic tasks, or even by the validated misophonia questionnaires for children that are fortunately now emerging (e.g., Rappoldt et al., 2024; Rinaldi et al., 2022).

Participants in this study were sometimes attending school or sometimes away from school due to summer break; others were homeschooled. Such differences in participants' real-world sensory environments may have influenced responses to the questionnaires. It is also possible participants' responses to multiple measures intended to address similar constructs were influenced by order effects, but we did not systematically manipulate or counterbalance order, so we cannot assess this.

Furthermore, while debates on representativeness of autism studies often focus on online research (e.g., Rødgaard et al., 2022), similar issues affect in-person studies. As study advertising referred to sensory experiences, participants facing unusually serious sensory barriers may have been more likely to be recruited.

Lastly, the present study has very limited representation in terms of gender (exacerbated by the exclusion of some female participants who did not meet autism criteria when seen by clinicians) and no representation of participants with intellectual disabilities, and many of the measures used in this study were not designed to be accessible for people with intellectual disabilities. Future research should strive to develop rigorous measures of highly specific sensory phenotypes that are accessible for neurodivergent individuals with and without intellectual disabilities, including children.

Summary

The present study used multiple methods to rigorously characterise auditory sensory phenotypes in autistic adolescents, finding, relative to controls, evidence of more auditory fear/panic experiences, more misophonia, more auditory distractibility, more hyperacusis and/or experiences of

auditory overwhelm, more impact of auditory sensory distress on daily quality of life, and more negative ratings of conventionally-pleasant sounds at modest intensity levels, perhaps reflecting aversions to particular sound patterns rather than discomfort caused by loudness/volume alone. The study's autistic adolescents appeared to self-report less atypical sensory experiences than described in their caregivers' proxy reports, the opposite of the patterns seen in prior research with autistic young people, raising questions about the factors driving differences between reporters' observations. Furthermore, although the study found evidence of convergence between some psychoacoustic and questionnaire-based measures of misophonia, self-reported and psychoacoustic measures of hyperacusis failed to converge, emphasizing the complexity of the constructs underlying atypical sensory experiences and the difficulties involved in measuring them. Future studies should endeavour to develop and validate measures of specific sensory constructs such as misophonia in autistic children and youth, including those with intellectual disabilities or who do not speak verbally; to continue efforts to explore the construct of loudness hyperacusis and its relationship to constructs such as sensory overload; and to collect additional measures (e.g., of interoception, autonomic arousal, identity) and/or conduct cognitive interviews that may aid in understanding differences between caregiver- and self-reports.

Acknowledgements We are grateful to Aryana Alavi, Aubrey Andrews, Lynnette H. Hersh, Shanzeh Iqbal, Jessica Jones, Meha Krishnareddigari, Moises De Jesus Lopez, Mia Lum, Mary S. Rose, and Jack Zembsch, who, as research assistants in the Neurocognitive Development Lab, were absolutely vital in our efforts to collect data for this study. We thank C. Steve Grugan, who as the lab manager in the period immediately before data collection began, had a crucial role in training and preparing our lab team for the study. We thank Kimberly Barajas, Lesley Deprey, Danielle R. Haener, Sally Ozonoff, Brittani A. Phillips, Dorcas L. Roa, Brenda Shelton, and Rhonda L. Wayne from the MIND Institute Research clinic for facilitating and conducting clinical assessments. We thank collaborators and colleagues for sharing materials and tasks, particularly Jacek Kolacz (BBCSS), and Zachary J. Williams (MIST-A, VADQ, and DVMSQ). Lastly, but certainly not least– indeed, most importantly of all– we are grateful to study participants and their family members, who took a great deal of time out of their often-busy lives in order to contribute to our research, and to community members who provided advice and insights to guide this study.

Author Contributions This study was designed by PD, CDS, and SMR. FE and AN provided code and technical support related to the Core Discriminant Sounds task. Data were collected by PD, AS, and others named in the acknowledgements section. PD conducted statistical analyses and drafted this paper, which was read, edited, and approved by all authors.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. Study funding was provided through an Autism Speaks / Royal Arch Masons predoctoral fellowship, by HRSA's Autism Intervention Research Network for Physical Health (AIR-P), by the Tsakopoulos Foundation, and by the UC Davis MIND Institute's Intellectual and Developmental Disability Research Centre (NICHD P50 HD103526).

Declarations

Ethical Approval This study was approved by the University of California, Davis institutional review board.

Conflict of Interest The authors have no conflicts of interest to report.

References

Aazh, H., Erfanian, M., Danesh, A. A., & Moore, B. C. J. (2022). Audiological and other factors predicting the presence of misophonia symptoms among a clinical population seeking help for tinnitus and/or hyperacusis. *Frontiers in Neuroscience*, *16*, 900065. https://doi.org/10.3389/fnins.2022.900065

Ash, P. A., Benzaquén, E., Gander, P. E., Berger, J. I., & Kumar, S. (2023). Mimicry in misophonia: A large-scale survey of prevalence and relationship with trigger sounds. *Journal of Clinical Psychology*, jclp.23605. https://doi.org/10.1002/jclp.23605

Ausderau, K., Sideris, J., Furlong, M., Little, L. M., Bulluck, J., & Baranek, G. T. (2014). National survey of sensory features in children with ASD: Factor structure of the sensory experience questionnaire (3.0). *Journal of Autism and Developmental Disorders*, *44*(4), 915–925. https://doi.org/10.1007/s10803-013-1945-1

Bandstra, N. F., Johnson, S. A., Filliter, J. H., & Chambers, C. T. (2012). Self-reported and parent-reported pain for common painful events in high-functioning children and adolescents with autism spectrum disorder. *Clinical Journal of Pain*, *28*(8), 715–721. https://doi.org/10.1097/AJP.0b013e318243ecf6

Baranek, G. T., Woynaroski, T. G., Nowell, S., Turner-Brown, L., DuBay, M., Crais, E. R., & Watson, L. R. (2018). Cascading effects of attention disengagement and sensory seeking on social symptoms in a community sample of infants at-risk for a future diagnosis of autism spectrum disorder. *Developmental Cognitive Neuroscience*, *29*, 30–40. https://doi.org/10.1016/j.dcn.2017.08.006

Belek, B. (2018). Articulating sensory sensitivity: From bodies with autism to autistic bodies. *Medical Anthropology*, *38*(1), 30–43. https://doi.org/10.1080/01459740.2018.1460750

Ben-Sasson, A., Gal, E., Fluss, R., Katz-Zetler, N., & Cermak, S. A. (2019). Update of a meta–analysis of sensory symptoms in ASD: A new decade of research. *Journal of Autism and Developmental Disorders*, *49*(12), 4974–4996. https://doi.org/10.1007/s10803-019-04180-0

Berument, S. K., Rutter, M., Lord, C., Pickles, A., & Bailey, A. (1999). Autism screening questionnaire: Diagnostic validity. *British Journal of Psychiatry*, *175*, 444–451. https://doi.org/10.1192/bjp.175.5.444

British Society of Audiology (2011). *Recommended procedure: Determination of uncomfortable loudness levels*. https://www.thebsa.org.uk/resources/determination-uncomfortable-loudness-levels/

Chistol, L. T., Bandini, L. G., Must, A., Phillips, S., Cermak, S. A., & Curtin, C. (2018). Sensory sensitivity and food selectivity in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *48*(2), 583–591. https://doi.org/10.1007/s10803-017-3340-9

Christensen, R. H. B. (2022). *ordinal—Regression Models for Ordinal Data*. https://CRAN.R-project.org/package=ordinal.

R Core Team (2022). *R: A language and environment for statistical computing*. https://www.R-project.org/

Davis, G., & Plaisted-Grant, K. (2015). Low endogenous neural noise in autism. *Autism*, *19*(3), 351–362. https://doi.org/10.1177/1362361314552198

Demopoulos, C., & Lewine, J. D. (2016). Audiometric profiles in autism spectrum disorders: Does subclinical hearing loss impact communication? *Autism Research*, *9*(1), 107–120. https://doi.org/10.1002/aur.1495

Dempsey, E. E., Moore, C., Johnson, S. A., Stewart, S. H., & Smith, I. M. (2022). Moral foundations theory among autistic and neurotypical children. *Frontiers in Psychology*, *12*, 782610. https://doi.org/10.3389/fpsyg.2021.782610

Dunlop, W. A., Enticott, P. G., & Rajan, R. (2016). Speech discrimination difficulties in high-functioning autism spectrum disorder are likely independent of auditory hypersensitivity. *Frontiers in Human Neuroscience*, *10*, 401. https://doi.org/10.3389/fnhum.2016.00401

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and Young Children*, *9*(4), 23–35.

Dwyer, P., Takarae, Y., Zadeh, I., Rivera, S. M., & Saron, C. D. (2022). A multidimensional investigation of sensory processing in autism: Parent- and Self-Report questionnaires, psychophysical thresholds, and Event-Related potentials in the auditory and somatosensory modalities. *Frontiers in Human Neuroscience*, *16*, 811547. https://doi.org/10.3389/fnhum.2022.811547

Dwyer, P., Sillas, A., Saron C. D., & Rivera, S. M. (2024). *Investigating autistic hyper-focusand monotropism: Limited convergence of event-related potentials, laboratory tasks, and questionnaire responses*. Preprint. https://doi.org/10.31234/osf.io/4k9bg

Dwyer, P., Williams, Z. J., Lawson, W., & Rivera, S. M. (2025). *A transdiagnostic study of attention and diverse phenotypes of "auditory hyperreactivity" in autism, ADHD, and the general population*. Preprint. https://doi.org/10.31234/osf.io/5p3eg

Enzler, F., Fournier, P., & Noreña, A. J. (2021a). A psychoacoustic test for diagnosing hyperacusis based on ratings of natural sounds. *Hearing Research*, *400*, 108124. https://doi.org/10.1016/j.heares.2020.108124

Enzler, F., Loriot, C., Fournier, P., & Noreña, A. J. (2021b). A psychoacoustic test for misophonia assessment. *Scientific Reports*, *11*, 11044. https://doi.org/10.1038/s41598-021-90355-8

Feldman, J. I., Raj, S., Bowman, S. M., Santapuram, P., Golden, A. J., Daly, C., Dunham, K., Suzman, E., Augustine, A. E., Garla, V., Muhumuza, A., Cascio, C. J., Williams, K. L., Kirby, A. V., Keceli-Kaysili, B., & Woynaroski, T. G. (2021). Sensory responsiveness is linked with communication in infant siblings of children with and without autism. *Journal of Speech Language & Hearing Research*, *64*, 1964–1976. https://doi.org/10.1044/2021_JSLHR-20-00196

Grandin, T., & Panek, R. (2014). *The autistic brain: Helping different kinds of Minds succeed*. Mariner Books.

Green, S. A., Ben-Sasson, A., Soto, T. W., & Carter, A. S. (2012). Anxiety and sensory over-responsivity in toddlers with autism spectrum disorders: Bidirectional effects across time. *Journal of Autism & Developmental Disorders*, *42*(6), 1112–1119. https://doi.org/10.1007/s10803-011-1361-3

Green, S. A., Hernandez, L. M., Bowman, H. C., Bookheimer, S. Y., & Dapretto, M. (2018). Sensory over-responsivity and social cognition in ASD: Effects of aversive sensory stimuli and attentional modulation on neural responses to social cues. *Developmental Cognitive Neuroscience*, *29*, 127–139. https://doi.org/10.1016/j.dcn.2017.02.005

Grosvenor, L. P., Whitney, D. G., Volk, H. E., & Fallin, M. D. (2021). Exploring a role for parental mental health in perception and reports of pain on behalf of children with autism spectrum disorder. *Autism Research and Treatment*, *2021*, 2981383. https://doi.org/10.1155/2021/2981383

Hansen, H., Leber, A., & Saygin, Z. (2021). What sound sources trigger misophonia? Not just chewing and breathing. *Journal of Clinical Psychology*, *77*(11), 2609–2625. https://doi.org/10.1002/jclp.23196

Harrell, F. (2022, October 14). *Package 'rms.'* Vanderbilt University. http://mirror.psu.ac.th/pub/cran/web/packages/rms/rms.pdf

Heller, L. M., & Smith, J. M. (2022). Identification of everyday sounds affects their pleasantness. *Frontiers in Psychology*, *13*, 894034. https://doi.org/10.3389/fpsyg.2022.894034

Ismael, N., Lawson, L. M., & Hartwell, J. (2018). Relationship between sensory processing and participation in daily occupations for children with autism spectrum disorder: A systematic review of studies that used dunn's sensory processing framework. *American Journal of Occupational Therapy*, *72*(3), 7203205030. https://doi.org/10.5014/ajot.2018.024075

Jager, I., de Koning, P., Bost, T., Denys, D., & Vulink, N. (2020). Misophonia: Phenomenology, comorbidity and demographics in a large sample. *PLOS ONE*, *15*(4), e0231390. https://doi.org/10.1371/journal.pone.0231390

Jastreboff, P. J., & Jastreboff, M. M. (2015). Decreased sound tolerance: Hyperacusis, misophonia, diplacousis, and polyacousis. In G. G. Celesia & G. Hickok (Eds.), *Handbook of Clinical Neurology* (Vol. 129, pp. 375–387). Elsevier. https://doi.org/10.1016/B978-0-444-62630-1.00021-4

Johnson, S. A., Filliter, J. H., & Murphy, R. R. (2009). Discrepancies between self- and parent-perceptions of autistic traits and empathy in high functioning children and adolescents on the autism spectrum. *Journal of Autism and Developmental Disorders*, *39*(12), 1706–1714. https://doi.org/10.1007/s10803-009-0809-1

Kassambara, A. (2022). *Package rstatix*.https://cran.r-project.org/web/packages/rstatix/rstatix.pdf

Keith, J. M., Jamieson, J. P., & Bennetto, L. (2019). The importance of adolescent self-report in autism spectrum disorder: Integration of questionnaire and autonomic measures. *Journal of Abnormal Child Psychology*, *47*, 741–754. https://doi.org/10.1007/s10802-018-0455-1

Kerns, C. M., Lankenau, S., Shattuck, P. T., Robins, D. L., Newschaffer, C. J., & Berkowitz, S. J. (2022). Exploring potential sources of childhood trauma: A qualitative study with autistic adults and caregivers. *Autism*. https://doi.org/10.1177/13623613211070637

Khalfa, S., Bruneau, N., Rogé, B., Georgieff, N., Veuillet, E., Adrien, J. L., Barthélémy, C., & Collet, L. (2004). Increased perception of loudness in autism. *Hearing Research*, *198*(1–2), 87–92. https://doi.org/10.1016/j.heares.2004.07.006

Kolacz, J., Raspa, M., Heilman, K. J., & Porges, S. W. (2018). Evaluating sensory processing in fragile X syndrome: Psychometric analysis of the brain body center sensory scales (BBCSS). *Journal of Autism and Developmental Disorders*, *48*(6), 2187–2202. https://doi.org/10.1007/s10803-018-3491-3

Kolesnik, A., Ali, J. B., Gliga, T., Guiraud, J., Charman, T., & Jones, E. J. H. (2019). Increased cortical reactivity to repeated tones at 8 months in infants with later ASD. *Translational Psychiatry*, *9*, 46. https://doi.org/10.1038/s41398-019-0393-x

Kumar, S., Dheerendra, P., Erfanian, M., Benzaquén, E., Sedley, W., Gander, P. E., Lad, M., Bamiou, D. E., & Griffiths, T. D. (2021). The motor basis for misophonia. *Journal of Neuroscience*. https://doi.org/10.1523/JNEUROSCI.0261-21.2021

Lau, B. Y., Leong, R., Uljarevic, M., Lerh, J. W., Rodgers, J., Hollocks, M. J., South, M., McConachie, H., Ozsivadjian, A., Hecke, A. V., Libove, R., Hardan, A., Leekam, S., Simonoff, E., & Magiati, I. (2020). Anxiety in young people with autism spectrum disorder: Common and autism-related anxiety experiences and their associations with individual characteristics. *Autism*, *24*(5), 1111–1126. https://doi.org/10.1177/1362361319886246

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule* (2nd ed.). Western Psychological Services.

MacLennan, K., Brien, S. O., & Tavassoli, T. (2022). In our own words: The complex sensory experiences of autistic adults. *Journal of Autism and Developmental Disorders*, 3061–3075. https://doi.org/10.1007/s10803-021-05186-3

McCormick, C., Hessl, D., Macari, S. L., Ozonoff, S., Green, C., & Rogers, S. J. (2014). Electrodermal and behavioral responses of children with autism spectrum disorders to sensory and repetitive stimuli. *Autism Research*, *7*, 468–480. https://doi.org/10.1002/aur.1382

Michel, L., Ricou, C., Bonnet-Brilhault, F., Houy-Durand, E., & Latinus, M. (2023). Sounds pleasantness ratings in autism: Interaction between social information and acoustical noise level. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-023-05989-6

Millington, E., Brown, L., McMahon, H., Robertson, A. E., & Simmons, D. (2021). Children's Glasgow sensory questionnaire (C-GSQ): Validation of a simplified and visually aided questionnaire. *PsyArXiv*. https://doi.org/10.31234/osf.io/f6bg2. Preprint.

Nader, A. M., Courchesne, V., Dawson, M., & Soulières, I. (2016). Does WISC-IV underestimate the intelligence of autistic children? *Journal of Autism and Developmental Disorders*, *46*(5), 1582–1589. https://doi.org/10.1007/s10803-014-2270-z

Norena, A. (2024). Did Kant suffer from misophonia? *Frontiers in Psychology*, *15*, 1242516. https://doi.org/10.3389/fpsyg.2024.1242516

Quinde-Zlibut, J. M., Okitondo, C. D., Williams, Z. J., Weitlauf, A., Mash, L. E., Heflin, B. H., Woodward, N. D., & Cascio, C. J. (2020). Elevated thresholds for light touch in children with autism reflect more Conservative perceptual decision-making rather than a sensory deficit. *Frontiers in Human Neuroscience*, *14*, 122. https://doi.org/10.3389/fnhum.2020.00122

Rappoldt, L. R., Kan, K. J., Dalmeijer, L., Rutten, S. A., Van Horen, R., Van Der Pol, M. M., De Wit, C., Denys, D., Vulink, N. C. C., & Utens, E. M. W. J. (2024). Psychometric validation of the new misophonia screening List—Child and youth and AMISOS-Y (Dutch Child- and Parent-Report Versions) for assessing misophonia in youth. *Child Psychiatry & Human Development*. https://doi.org/10.1007/s10578-024-01781-4

Remington, A., & Fairnie, J. (2017). A sound advantage: Increased auditory capacity in autism. *Cognition*, *166*, 459–465. https://doi.org/10.1016/j.cognition.2017.04.002

Rinaldi, L. J., Smees, R., Ward, J., & Simner, J. (2022). Poorer Well-Being in children with misophonia: Evidence from the Sussex misophonia scale for adolescents. *Frontiers in Psychology*, *13*, 808379. https://doi.org/10.3389/fpsyg.2022.808379

Ripley, B., Venables, B., Bates, D. M., Hornik, K., Gebhardt, A., & Firth, D. (2022, October 12). *Package MASS*.https://cran.r-project.org/web/packages/MASS/MASS.pdf

Rødgaard, E. M., Jensen, K., Miskowiak, K. W., & Mottron, L. (2022). Representativeness of autistic samples in studies recruiting through social media. *Autism Research*, *15*(8), 1447–1456. https://doi.org/10.1002/aur.2777

Rodgers, J., Wigham, S., McConachie, H., Freeston, M., Honey, E., & Parr, J. R. (2016). Development of the anxiety scale for children with autism spectrum disorder (ASC-ASD). *Autism Research*, *9*(11), 1205–1215. https://doi.org/10.1002/aur.1603

Savard, M. A., Sares, A. G., Coffey, E. B. J., & Deroche, M. L. D. (2022). Specificity of affective responses in misophonia depends on trigger identification. *Frontiers in Neuroscience*, *16*, 879583. https://doi.org/10.3389/fnins.2022.879583

Scheerer, N. E., Boucher, T. Q., Bahmei, B., Iarocci, G., Arzanpour, S., & Birmingham, E. (2022). Family experiences of decreased sound tolerance in ASD. *Journal of Autism and Developmental Disorders*, *52*, 4007–4021. https://doi.org/10.1007/s10803-021-05282-4

Scheydt, S., Müller Staub, M., Frauenfelder, F., Nielsen, G. H., Behrens, J., & Needham, I. (2017). Sensory overload: A concept analysis. *International Journal of Mental Health Nursing*, *26*, 110–120. https://doi.org/10.1111/inm.12303

Siepsiak, M., Turek, A., Michałowska, M., Gambin, M., & Dragan, W. Ł. (2023). Misophonia in children and adolescents: Age differences, risk factors, psychiatric and psychological correlates. A pilot study with mothers' involvement. *Child Psychiatry & Human Development*. https://doi.org/10.1007/s10578-023-01593-y

Siper, P. M., Kolevzon, A., Wang, A. T., Buxbaum, J. D., & Tavassoli, T. (2017). A clinician-administered observation and corresponding caregiver interview capturing DSM-5 sensory reactivity symptoms in children with ASD: Sensory assessment for neurodevelopmental disorders. *Autism Research*, *10*(6), 1133–1140. https://doi.org/10.1002/aur.1750

Sohal, V. S., & Rubenstein, J. L. R. (2019). Excitation-inhibition balance as a framework for investigating mechanisms in neuropsychiatric disorders. *Molecular Psychiatry*, *24*, 1248–1257. https://doi.org/10.1038/s41380-019-0426-0

Späth, E. M. A., & Jongsma, K. R. (2019). Autism, autonomy, and authenticity. *Medicine Health Care and Philosophy*, *2*(0123456789). https://doi.org/10.1007/s11019-019-09909-3

Strömberg, M., Liman, L., Bang, P., & Igelström, K. (2022). Experiences of sensory overload and communication barriers by autistic adults in health care settings. *Autism in Adulthood*, *4*(1), 66–75. https://doi.org/10.1089/aut.2020.0074

Swanson, J. M., Schuck, S., Porter, M. M., Carlson, C., Hartman, C. A., Sergeant, J. A., Clevenger, W., Wasdell, M., McCleary, R., Lakes, K., & Wigal, T. (2012). Categorical and dimensional definitions and evaluations of symptoms of ADHD: History of the SNAP and the SWAN rating scales. *The International Journal of Educational and Psychological Assessment*, *10*(1), 51–70.

Swedo, S. E., Baguley, D. M., Denys, D., Dixon, L. J., Erfanian, M., Fioretti, A., Jastreboff, P. J., Kumar, S., Rosenthal, M. Z., Rouw, R., Schiller, D., Simner, J., Storch, E. A., Taylor, S., Werff, K. R. V., Altimus, C. M., & Raver, S. M. (2022). Consensus definition of misophonia: A Delphi study. *Frontiers in Neuroscience*, *16*, 841816. https://doi.org/10.3389/fnins.2022.841816

Taels, L., Feyaerts, J., Lizon, M., De Smet, M., & Vanheule, S. (2023). I felt like my senses were under attack': An interpretative phenomenological analysis of experiences of hypersensitivity in autistic individuals. *Autism*. https://doi.org/10.1177/13623613231158182

Tavassoli, T., Bellesheim, K., Siper, P. M., Wang, A. T., Halpern, D., Gorenstein, M., Grodberg, D., Kolevzon, A., & Buxbaum, J. D. (2016). Measuring sensory reactivity in autism spectrum disorder: Application and simplification of a clinician-administered sensory observation scale. *Journal of Autism and Developmental*

Disorders, *46*(1), 287–293. https://doi.org/10.1007/s10803-015-2578-3

Trevisan, D. A., Mehling, W. E., & McPartland, J. C. (2021). Adaptive and maladaptive bodily awareness: Distinguishing interoceptive sensibility and interoceptive attention from anxiety-induced somatization in autism and alexithymia. *Autism Research*, *14*(2), 240–247. https://doi.org/10.1002/aur.2458

Tyler, R. S., Pienkowski, M., Rojas Roncancio, E., Jun, H. J., Brozoski, T., Dauman, N., Coelho, C. B., Andersson, G., Keiner, A. J., Cacace, A. T., Martin, N., & Moore, B. C. J. (2014). A review of hyperacusis and future directions: Part I. Definitions and manifestations. *American Journal of Audiology*, *23*, 402–419. https://doi.org/10.1044/2014_AJA-14-0010

Tzischinsky, O., Meiri, G., Manelis, L., Bar-Sinai, A., Flusser, H., Michaelovski, A., Zivan, O., Ilan, M., Faroy, M., Menashe, I., & Dinstein, I. (2018). Sleep disturbances are associated with specific sensory sensitivities in children with autism. *Molecular Autism*, *9*(1), 22. https://doi.org/10.1186/s13229-018-0206-8

Uljarević, M., Baranek, G., Vivanti, G., Hedley, D., Hudry, K., & Lane, A. (2017). Heterogeneity of sensory features in autism spectrum disorder: Challenges and perspectives for future research. *Autism Research*, *10*(5), 703–710. https://doi.org/10.1002/aur.1747

Wada, M., Hayashi, K., Seino, K., Ishii, N., Nawa, T., & Nishimaki, K. (2023). Qualitative and quantitative analysis of self-reported sensory issues in individuals with neurodevelopmental disorders. *Frontiers in Psychiatry*, *14*, 1077542. https://doi.org/10.3389/fpsyt.2023.1077542

Wagner, M., Newman, L., Cameto, R., Javitz, H., & Valdes, K. (2012). A National picture of parent and youth participation in IEP and transition planning meetings. *Journal of Disability Policy Studies*, *23*(3), 140–155. https://doi.org/10.1177/1044207311425384

Wechsler, D. (2011). *Wechsler abbreviated scale of Intelligence–Second edition (WASI-II)*. Pearson.

Williams, Z. J. (2021, May). *Vanderbilt Auditory Distractibility Questionnaire (VADQ)*. ResearchGate. https://doi.org/10.13140/RG.2.2.14831.36000

Williams, Z. J., He, J. L., Cascio, C. J., & Woynaroski, T. G. (2021). A review of decreased sound tolerance in autism: Definitions, phenomenology, and potential mechanisms. *Neuroscience and Biobehavioral Reviews*, *121*, 1–17. https://doi.org/10.1016/j.neubiorev.2020.11.030

Williams, Z. J., Cascio, C. J., & Woynaroski, T. G. (2022). Psychometric validation of a brief self-report measure of misophonia symptoms and functional impairment: The duke-vanderbilt misophonia screening questionnaire. *Frontiers in Psychology*, *13*, 897901. https://doi.org/10.3389/fpsyg.2022.897901

Williams, Z. J., Schaaf, R., Ausderau, K. K., Baranek, G. T., Barrett, D. J., Cascio, C. J., Dumont, R. L., Eyoh, E. E., Failla, M. D., Feldman, J. I., Foss-Feig, J. H., Green, H. L., Green, S. A., He, J. L., Kaplan-Kahn, E. A., Keçeli-Kaysılı, B., MacLennan, K., Mailloux, Z., Marco, E. J., & Woynaroski, T. G. (2023). *Examining the Latent Structure and Correlates of Sensory Reactivity in Autism: A Multi-site Integrative Data Analysis by the Autism Sensory Research Consortium* [Preprint]. In Review. https://doi.org/10.21203/rs.3.rs-2447849/v1

Williams, Z. J., Barrett, D. J., Dwyer, P., Keçeli-Kaysılı, B., Cascio, C. J., & Woynaroski, T. G. (2023 May). *Psychometric evaluation of the multidimensional inventory of sound tolerance in adults (MIST-A): A novel self-report measure assessing decreased sound tolerance symptomatology in autistic and non-autistic adults*. International Society for Autism Research (INSAR).

Wodka, E. L., Puts, N. A. J., Mahone, E. M., Edden, R. A. E., Tommerdahl, M., & Mostofsky, S. H. (2016). The role of attention in somatosensory processing: A Multi-trait, Multi-method analysis. *Journal of Autism and Developmental Disorders*, *46*(10), 3232–3241. https://doi.org/10.1007/s10803-016-2866-6

Yafai, A. F., Verrier, D., & Reidy, L. (2014). Social conformity and autism spectrum disorder: A child-friendly take on a classic study. *Autism*, *18*(8), 1007–1013. https://doi.org/10.1177/1362361313508023