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Risk factors and clinical correlates of sensory dysfunction in preschool children with and without autism spectrum disorder

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Abstract

Sensory dysfunction is a common feature of autism spectrum disorder (ASD). The objectives of this analysis were to examine risk factors and clinical correlates of sensory dysfunction in preschool children with and without ASD. Children aged 2–5 years were enrolled in a multi-site case–control study. Data were collected in eight areas across the United States in three phases. Caregivers completed an interview with questions on assisted delivery, maternal alcohol use, maternal anxiety during pregnancy, pregnancy weight gain, neonatal jaundice, preterm birth, and child sensory diagnosis given by a healthcare provider. Caregivers also completed an interview and questionnaires on sensory symptoms and clinical correlates of sensory dysfunction in their child. There were 2059 children classified as ASD, 3139 as other developmental delay or disability (DD), and 3249 as population comparison (POP). Caregivers reported significantly more sensory diagnoses and sensory symptoms in children classified as ASD than DD or POP (23.7%, 8.6%, and 0.8%, respectively, for a sensory diagnosis and up to 78.7% [ASD] vs. 49.6% [DD] for sensory symptoms). Maternal anxiety during pregnancy and neonatal jaundice were significantly associated with a sensory diagnosis and certain sensory symptoms in children with ASD and DD. Children's anxiety, attention deficits/hyperactivity, and sleep problems were significantly albeit subtly correlated with both a sensory diagnosis and sensory symptoms in children with ASD and DD. These findings support sensory dysfunction as a distinguishing symptom of ASD in preschool

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children and identify risk factors and clinical correlates to inform screening and treatment efforts in those with atypical development.

Lay Summary

We found that sensory dysfunction was more common in children with autism than children without autism. Maternal anxiety during pregnancy and neonatal jaundice were related to children's sensory outcomes, as were and children's anxiety, attention deficits/hyperactivity, and sleep problems. Screening for sensory dysfunction in children with specific risk factors and clinical characteristics may help identify appropriate treatment strategies.

Keywords

anxiety; autism; jaundice; risk factors; sensory

Sensory dysfunction, or abnormal response to sensory input, is one of the most common features of autism spectrum disorder (ASD). It is reported to affect between 45% and 95% of persons with ASD (Ben-Sasson et al., 2019) and is associated with reduced quality of life (Lin & Huang, 2019; MacLennan et al., 2022). Some people with lived experiences identify sensory dysfunction as a core feature of ASD that negatively impacts mental and physical health (MacLennan et al., 2022). Another reported outcome of sensory dysfunction is disengagement from the social environment (MacLennan et al., 2022). Sensory dysfunction may therefore have a cascading and harmful influence on social development and other areas of functioning (Baranek et al., 2018; Cascio et al., 2016).

Sensory dysfunction is an important component of the ASD phenotype in early childhood. For instance, sensory dysfunction distinguishes preschool children with ASD from those with subthreshold ASD characteristics (Wiggins et al., 2015) and contributes to homogeneity within the autism spectrum (Wiggins et al., 2022). Understanding risk factors and clinical correlates of sensory dysfunction in early childhood may reinforce heightened screening and precision therapies to support development and decrease troubling symptoms later in life. Yet, little is known about risk factors for sensory dysfunction in young children.

In general, assisted delivery (May-Benson et al., 2009), maternal stress during pregnancy (Gandara-Gafo et al., 2021), maternal weight gain during pregnancy (Crepeau-Hobson, 2009), prenatal alcohol exposure (Fieldsted & Xue, 2019; Hansen & Jirikowic, 2013; Jirikowic et al., 2020), and premature birth (André et al., 2020; Crepeau-Hobson, 2009; Crozier et al., 2016; Ryckman et al., 2017; Wickremasinghe et al., 2013) are pre- and perinatal risk factors for sensory dysfunction. Maternal stress during pregnancy and prenatal alcohol exposure have also been shown to increase sensory difficulties in non-human primates (Schneider et al., 2008). After birth, neonatal jaundice (Wickremasinghe et al., 2013) and childhood lead exposure (Cai et al., 2019) have been associated with sensory differences in children born preterm and those from the general population. These studies offer important clues to risk factors that may also lead to sensory dysfunction in young children with ASD and other developmental delays and disabilities (DD).

In terms of clinical correlates, both ASD and sensory dysfunction are associated with adaptive delays (Kirby et al., 2022; Tillman et al., 2020), anxiety (MacLennan et al., 2020; Mazurek et al., 2013; Tillman et al., 2020), attention deficits (Kirby et al., 2022; Tillman et al., 2020), and sleep disturbance (Kirby et al., 2022; Tillman et al., 2020). Much of the literature on clinical correlates focuses on older children, and there are no identified studies that examine these same correlates in young children around the age of first ASD diagnosis and treatment. Given these limitations and gaps in the literature, our goals were to examine both risk factors and clinical correlates of sensory dysfunction in preschool children with and without ASD to inform early identification and treatment efforts.

METHODS

Data for this analysis are from the Study to Explore Early Development (SEED). SEED is a retrospective multi-site case–control study on the risk factors and behavioral phenotypes of ASD sponsored by the Centers for Disease Control and Prevention (CDC). To date, three phases of SEED have been completed. In the first two phases, data were collected in California, Colorado, Georgia, Maryland, North Carolina, and Pennsylvania. In the third phase, data were collected in Colorado, Georgia, Maryland, Missouri, North Carolina, and Wisconsin. All sites adhered to a common protocol that was approved by Institutional Review Boards at CDC and each study site.

Children between 2 and 5 years of age were identified from a broad range of diagnostic codes at clinic sources (potential cases) or randomly selected from birth certificate records (controls). All children were screened for ASD with the Social Communication Questionnaire (SCQ; Rutter et al., 2003) at study enrollment and asked to complete the Mullen Scales of Early Learning (MSEL; Mullen, 1995). The MSEL is a standardized evaluation of early learning abilities that has a mean of 100 points and standard deviation of 15 points, with higher scores indicating more advanced abilities. Children who had an existing ASD diagnosis or had ASD risk on the SCQ (i.e., those classified as ASD and a subset of those classified as DD) also received two standardized diagnostic instruments: the Autism Diagnostic Interview Revised (ADI-R; Lord et al., 1994) and Autism Diagnostic Observation Schedule (ADOS; Gotham et al., 2007). ASD case status was determined by results of the ADI-R and ADOS. Final study classifications were ASD, other DD, and population comparison (POP). See Schendel et al. (2012) and Wiggins et al. (2015) for more details on SEED methods and final classification procedures.

Definitions of sensory dysfunction

Several definitions of sensory dysfunction were used in this study. The first definition was “sensory diagnosis.” The authors acknowledge that “sensory diagnosis” is not included in diagnostic systems such as the Diagnostic and Statistical Manual of Mental Disorders. However, some providers use this term to describe recognized sensory dysfunction in the child, which was the primary outcome of interest in this study. Thus, sensory diagnosis was measured via caregiver response to the question “Has a doctor or other healthcare provider ever told you that this child has sensory integration disorder?” Caregivers were also asked to provide additional child diagnoses, and free-text responses of “sensory disorder,” “sensory

processing disorder," and similar were included in this definition. Caregivers of children in all 3 study groups were asked to answer this question.

Subsequent definitions were defined by three items on the ADI-R. The ADI-R was administered by clinicians who established and maintained administration fidelity and scoring reliability throughout the study. The items used in this analysis asked about current unusual sensory interests, negative response to noise, and idiosyncratic response to certain stimuli. Scores of 0 represented no sensory symptoms and scores of 1, 2, or 3 represented sensory symptoms at varying levels of impairment. For this analysis, scores of 1, 2, or 3 were combined to represent the presence of any current sensory symptoms. The ADI-R was given only to children with ASD and a subsample of children with DD who had a previous ASD diagnosis or demonstrated ASD risk on the SCQ. The ADI-R was not systemically given to children in the POP group.

Risk factors for sensory dysfunction

Caregivers of children enrolled in SEED were asked to complete an interview about maternal health and exposures during pregnancy and sociodemographic characteristics of the study sample (98% of respondents were the biological mother of the child). Independent variables included in this study were those found to be associated with sensory dysfunction in previous studies and were collected on the caregiver interview: assisted delivery, preterm birth, maternal alcohol use, maternal anxiety during pregnancy, pregnancy weight gain, and neonatal jaundice. Assisted delivery was defined as use of forceps or vacuum extraction. Preterm birth was defined as gestational age < 37 weeks; information from birth certificates was used to supplement parent report for this measure. Maternal anxiety during pregnancy diagnosed by a healthcare provider was assessed via caregiver report. Similarly, alcohol use from 3 months before pregnancy until the end of breastfeeding and the presence of neonatal jaundice was assessed via caregiver report. Pregnancy weight gain was categorized according to guidelines published by the American College of Obstetricians and Gynecologists (2013) as met weight gain recommendations, above recommendations, and below recommendations.

Clinical correlates of sensory dysfunction

Adaptive delays—The Vineland Adaptive Behavior Scales – Second edition (VABS; Sparrow, Balla, & Cicchetti, 2005) is a semistructured caregiver interview used to determine adaptive abilities. Individual skills are probed in a conversational format and rated by the interviewer as "0 = not performed or rarely performed without help or reminders," "1 = sometimes or partially performed without help or reminders," and "2 = usually or regularly performed without help or reminders." The VABS yields four domain scores that represent communication, daily living, motor, and social abilities. These scores are combined to create an adaptive behavior composite (ABC) that has a mean of 100 points and standard deviation of 15 points, with higher scores indicating more advanced abilities. VABS ABC scores of less than 85 indicate overall adaptive delays; this cut-off was used to define the presence or absence of adaptive delays in these analyses. The VABS was given only to children with ASD and a subsample of children with DD who had a previous ASD diagnosis or

demonstrated ASD risk on the SCQ. The VABS was not systemically given to children in the POP group.

Anxiety, attention, and sleep problems—The Child Behavior Checklist—1 1/5—5-year-old version (CBCL; Achenbach, 2013) is a widely used standardized assessment of child behavior problems that contains 99 behaviors rated by a caregiver as "0 = not true," "1 = somewhat or sometimes true," or "2 = very true or often true." The CBCL yields five Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition oriented subscales including affective problems, anxiety problems, pervasive developmental problems, attention deficit/hyperactivity problems, and oppositional problems. The CBCL also yields a separate empirically based scale for sleep problems. Higher CBCL scores indicate more behavior problems. CBCL t-scores of 65 or higher indicate borderline to clinically significant problems in the child; this cut-off was used to define the presence or absence of anxiety problems, attention deficit/hyperactivity, or sleep problems in these analyses. The CBCL was given to all caregivers of children enrolled in the first two phases of SEED and to caregivers of children in the ASD and POP groups in the third phase of SEED.

Statistical analyses

Descriptive statistics were used to characterize the sociodemographic and phenotypic variables in the SEED 1–3 sample. ANOVA analyses were used to compare mean differences in child age at enrollment and MSEL early learning composite scores between ASD, DD, and POP groups. Chi-square analyses were used to compare differences in household income as a percent of federal poverty level (≤100%, 101%–399%, and ≥400%), maternal education (high school or less, some college, and college graduate), and maternal race/ethnicity (Hispanic, non-Hispanic Black, non-Hispanic White, and Other) between ASD, DD, and POP groups. Chi-square analyses were also used to compare differences in adaptive delays (no/yes), behavior problems (anxiety no/yes, attention deficit/hyperactivity no/yes, and sleep problems no/yes), child sex (male/female), and sensory dysfunction (sensory diagnosis no/yes, unusual sensory interests no/yes, negative response to noise no/yes, and idiosyncratic response to certain stimuli no/yes). Finally, chi-square analyses were used to compare differences in the presence of risk factors for sensory dysfunction (i.e., assisted delivery no/yes, preterm birth no/yes, maternal alcohol use no/yes, maternal anxiety during pregnancy no/yes, neonatal jaundice no/yes, pregnancy weight gain recommendations met/above/below) between ASD, DD, and POP groups. A priori statistical significance for chi-square analyses was set at <0.01 given multiple comparisons.

Binary logistic regression models were used to assess the relationship between sensory dysfunction and the risk factors previously noted. Separate analyses were conducted for children with ASD and other DD. Models with sensory diagnosis and with specific sensory symptoms were run separately. All regression models were adjusted for child age, child sex, household income relative to federal poverty threshold, maternal education, maternal race/ethnicity, and MSEL total score. Adjusted odds ratios (aOR) and 95% confidence intervals (CI) were reported. Finally, a bivariate correlation matrix showed correlations between sensory diagnosis, sensory symptoms, adaptive delays, anxiety problems, attention deficits/hyperactivity, and sleep problems in the child. Correlation analyses were unadjusted

to highlight significant associations that could inform screening, monitoring, and treatment efforts. Correlations of <0.30 were considered subtle, and correlations ≥0.30 were considered moderate. *p*-Values indicated statistical significance at <0.05.

RESULTS

There were 8447 children in SEED who were classified as ASD (*N* = 2059), other DD (*N* = 3139), or POP (*N* = 3249). Of those, males comprised 80.9% of the ASD group, 64.2% of the DD group, and 52.2% of the POP group. Mean early learning composite scores were 63.7 for the ASD group, 85.2 for the DD group, and 102.1 for the POP group. The percentage of children who met study criteria for sensory disorder was statistically different for ASD (23.7%), other DD (8.6%), and POP (0.8%) groups. Similarly, the percent of children who met study criteria for specific sensory symptoms was statistically different for ASD (38.6%–78.7%) and other DD (26.0%–49.6%) groups. Other sociodemographic and phenotypic characteristics of the study sample are provided in Tables 1 and 2.

There were statistically significant differences between study groups in risk factors for sensory dysfunction (Table 3). The ASD group had higher percent endorsement than the DD and POP groups for maternal weight gain during pregnancy above recommendations and higher percent endorsement for assisted delivery and preterm birth than the POP group. The DD group had higher percent endorsement than the ASD and POP groups for preterm birth and maternal weight gain during pregnancy below recommendations. The POP group had higher percent endorsement than the ASD or DD groups for maternal alcohol use. There were no statistically significant differences between the ASD and DD groups in terms of maternal anxiety during pregnancy or neonatal jaundice, but both were significantly higher than the POP group.

Assisted delivery and maternal alcohol use were excluded from logistic regression models since these variables had significantly more missing data than others and models did not converge when they were included (Table 3). Maternal anxiety during pregnancy and neonatal jaundice were significantly associated with sensory diagnosis in children with ASD and other DD (Table 4). Risk factors for specific sensory symptoms differed by ASD status. For children with ASD, maternal anxiety during pregnancy was associated with idiosyncratic response to certain stimuli. For children with other DD, neonatal jaundice was associated with negative response to noise and idiosyncratic response to certain stimuli (Table 4).

In terms of clinical correlates, among both children with ASD and children with other DD, child's anxiety problems, attention deficits/hyperactivity, and sleep problems were significantly correlated with each other, and adaptive delays were significantly correlated with attention deficits/hyperactivity (Table 5). Anxiety was significantly albeit subtly correlated with sensory diagnosis and all three sensory symptoms in children with ASD and children with other DD. Attention deficits/hyperactivity and sleep problems were significantly correlated with a sensory diagnosis and at least one sensory symptom, and adaptive delays were correlated with unusual sensory interests in both study groups.

DISCUSSION

Sensory dysfunction is a common feature of ASD in preschool children. We found that 23.7% of preschool children with ASD in SEED had been diagnosed with sensory disorder by a healthcare provider; this estimate was significantly higher than children with DD and POP (8.6% and 0.8%, respectively). The most common sensory symptom in children with ASD was unusual sensory interests (78.7%) followed by negative response to noise (64.6%) and idiosyncratic response to specific stimuli(38.6%). These estimates were significantly higher than children with other DD (46.7%, 49.6%, and 26.0%, respectively). Overall, these findings support the idea that sensory dysfunction is a distinguishing symptom of ASD in early childhood that offers potential as an early screening and treatment target (Bizzell et al., 2020).

Understanding risk factors for sensory dysfunction could support heightened screening in certain populations and offer clues to etiologic pathways of development. Our findings highlight maternal anxiety during pregnancy and neonatal jaundice as the most robust predictors of sensory dysfunction in children with ASD and other DD. Maternal anxiety during pregnancy was associated with a diagnosis of sensory disorder in children with ASD and other DD and idiosyncratic response to certain stimuli in children with ASD. Maternal anxiety during pregnancy has been associated with a range of adverse childhood outcomes, including increased risk of affective and anxiety disorders and executive functioning deficits, and clinical diagnoses of attention-deficit/hyperactivity disorder (ADHD) and ASD (Lautarescu et al., 2020). Underlying mechanisms in animal and human models have primarily focused on the hypothalamic–pituitary–adrenal axis and role of prenatal cortisol exposure on fetal brain development (Lautarescu et al., 2020). Integrating mental health services into primary care and identifying best mental health practices for pregnant women may increase access to effective care during this critical period (Payne et al., 2020).

Neonatal jaundice was associated with a diagnosis of sensory disorder in children with ASD and other DD. Neonatal jaundice was also associated with negative response to noise and idiosyncratic response to certain stimuli in children with other DD. Some previous studies support a link between neonatal jaundice and executive functioning deficits and clinical diagnoses of ADHD and ASD; yet, results are mixed and have not always been replicated in later analyses (Wusthoff & Loe, 2015). Theories on underlying mechanisms suggest that heightened bilirubin crosses the blood–brain barrier and causes encephalopathy and neurological impairment in the child (Kemper et al., 2022; Wusthoff & Loe, 2015). Heightened bilirubin is sometimes detected with visual examination, but total serum bilirubin or transcutaneous bilirubin measures are recommended (Muchowski, 2014). Heightened bilirubin can be treated with phototherapy and, for more severe cases, exchange transfusion (Kemper et al., 2022; Muchowski, 2014).

Clinical correlates of sensory dysfunction found in previous studies were also implicated albeit subtly among children with ASD and DD in this study. Specifically, anxiety problems, attention deficits/hyperactivity, and sleep problems had significant and positive relationships with both sensory diagnosis and at least one sensory symptom, and with each other. These correlates are more prevalent in preschool children with ASD than those with other DD

(Wiggins et al., 2015) and may exacerbate sensory dysfunction in the child, and vice versa. Moreover, both maternal anxiety during pregnancy and neonatal jaundice have been associated with ASD and one or more of these correlates in other studies, suggesting a complex connection between these specific risk factors and childhood outcomes (Lautarescu et al., 2020; Wusthoff & Loe, 2015). Thus, if a child presents with one of these symptoms, they may demonstrate sensory dysfunction as well as the other clinical symptoms and could be screened, monitored, and treated accordingly.

The strengths of this study are the community-based recruitment strategy, comprehensive data collection protocol, comprehensive evaluation of children, large sample size for diverse study groups, and standardized definitions of children with and without ASD. Some limitations are retrospective caregiver report of risk factors for sensory dysfunction and inclusion of “sensory diagnosis” and interview items as outcomes rather than a standardized measure that evaluates specific components of sensory dysfunction in preschool children (e.g., over-responsiveness, under-responsiveness vs. sensory seeking). Other limitations are that SEED did not systematically collect information on adaptive delays, behavior problems, and sensory symptoms across all phases in all study groups or collect information on childhood lead exposure, which could limit generalizability of the findings. Finally, there were too much missing data on assisted delivery and maternal alcohol use by trimester to conduct meaningful logistic regression analyses.

In conclusion, our findings highlight sensory dysfunction as a common symptom of ASD in preschool children. Maternal anxiety during pregnancy and neonatal jaundice were robust risk factors for a sensory diagnosis in children with ASD and DD. Maternal anxiety during pregnancy was associated with specific sensory symptoms in children with ASD, whereas neonatal jaundice was associated with specific sensory symptoms in children with other DD. These results suggest that heightened screening for sensory dysfunction may be appropriate for young children with these specific exposures. Understanding how these exposures could lead to sensory dysfunction may help identify primary prevention strategies. Other avenues for future research may include identifying risk factors for unusual sensory interests, examining whether other maternal mental health diagnoses are associated with sensory dysfunction, and exploring genetic contributions to the associations found in this analysis. Finally, sensory dysfunction was correlated with children’s anxiety problems, attention deficits/hyperactivity, and sleep problems. Thus, screening and emphasizing coordinated care for these interrelated clinical symptoms in comprehensive treatment plans may be beneficial.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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TABLE 1

Sociodemographic characteristics of preschool children enrolled in the Study to Explore Early Development Phases 1–3, stratified by study group.

	ASD	DD	POP	ASD:DD	ASD:POP	DD:POP
	***N* = 2059**	***N* = 3139**	***N* = 3249**	***p*-Value**	***p*-Value**	***p*-Value**
	***N* (%)**	***N* (%)**	***N* (%)**			
Child sex						
Female	394 (19.1)	1123 (35.8)	1552 (47.8)	<0.01	<0.01	<0.01
Male	1665 (80.9)	2016 (64.2)	1697 (52.2)			
Household income relative to federal poverty threshold						
≤100%	185 (9.5)	274 (10.7)	159 (6.1)	0.27	<0.01	<0.01
101%−399%	751 (38.5)	937 (36.5)	743 (28.3)			
≥400%	1015 (52.0)	1355 (52.8)	1719 (65.6)			
Missing	108	573	628			
Maternal education						
High school or less	406 (19.8)	713 (23.0)	483 (15.0)	<0.01	<0.01	<0.01
Some college	630 (30.7)	752 (24.3)	709 (22.0)			
College graduate	1018 (49.5)	1633 (52.7)	2032 (63.0)			
Missing	5	41	25			
Maternal race/ethnicity						
Hispanic	268 (13.1)	438 (15.1)	321 (10.8)	<0.01	<0.01	<0.01
Non-Hispanic Black	483 (23.5)	670 (23.1)	497 (16.7)			
Non-Hispanic White	1079 (52.6)	1740 (60.0)	2093 (70.4)			
Other	222 (10.8)	52 (1.8)	64 (2.1)			
Missing	7	239	274			

Note: *p*-Values do not include missing categories.

Abbreviations: ASD, autism spectrum disorder; DD, other developmental delay disability; POP, population comparison.

TABLE 2

Phenotypic characteristics of preschool children enrolled in the Study to Explore Early Development Phases 1–3, stratified by study group.

	ASD	**DD**	**POP**	**ASD:DD**	**ASD:POP**	**DD:POP**
	***N* = 2059**	***N* = 3139**	***N* = 3249**	***p*-Value**	***p*-Value**	***p*-Value**
	Mean	**Mean**	**Mean**			
Child age at enrollment (months)	51.7	52.6	50.8	<0.01	<0.01	<0.01
Early learning composite score	63.7	85.2	102.1	<0.01	<0.01	<0.01
	***N* (%)**	***N* (%)**	***N* (%)**			
Adaptive delays						
No	335 (16.5)	446 (40.6)	/	<0.01	/	/
Yes	1699 (83.5)	653 (59.4)	/			
Missing	25	2040	/			
Behavior problems						
Anxiety						
No	1572 (78.6)	1696 (86.6)	2322 (96.1)	<0.01	<0.01	<0.01
Yes	429 (21.4)	263 (13.4)	95 (3.9)			
Missing	58	1180	832			
Attention deficits/hyperactivity						
No	1408 (70.4)	1697(86.6)	2365 (97.8)	<0.01	<0.01	<0.01
Yes	593 (29.6)	262 (13.4)	52 (2.2)			
Missing	58	1180	832			
Sleep problems						
No	1583 (79.1)	1732 (88.4)	2327 (96.3)	<0.01	<0.01	<0.01
Yes	418 (20.9)	227 (11.6)	90 (3.7)			
Missing	58	1180	832			
Sensory dysfunction						
Sensory diagnosis						
No	1536 (76.3)	2464 (91.4)	2660 (99.2)	<0.01	<0.01	<0.01
Yes	477 (23.7)	233 (8.6)	22 (0.8)			
Missing	46	442	567			
Unusual sensory interests						

	ASD	DD	POP	ASD:DD	ASD:POP	DD:POP
	***N* = 2059**	***N* = 3139**	***N* = 3249**	***p*-Value**	***p*-Value**	***p*-Value**
No	448 (21.3)	390 (53.3)	/	<0.01	/	/
Yes	1609 (78.7)	342 (46.7)	/			
Missing	2	2407	/			
Negative response to noise						
No	728 (35.4)	353 (50.4)	/	<0.01	/	/
Yes	1328 (64.6)	377 (49.6)	/			
Missing	3	2409	/			
Idiosyncratic response to certain stimuli						
No	1262 (61.4)	540 (74.0)	/	<0.01	/	/
Yes	792 (38.6)	190 (26.0)	/			
Missing	5	2409	/			

Note: *p*-Values do not include missing categories; adaptive delays, unusual sensory interests, negative response to noise, and idiosyncratic response to certain stimuli were not measured in POP children (denoted with a/symbol) and only a subset of DD children; and behavior problems were measured only in a subset of DD children. Abbreviations: ASD, autism spectrum disorder; DD, other developmental delay or disability; POP, population comparison.

TABLE 3

Risk factors for sensory dysfunction collected in Study to Explore Early Development Phases 1–3, stratified by study group.

	ASD	DD	POP	ASD:DD	ASD:POP	DD:POP
	***N* = 2059**	***N* = 3139**	***N* = 3249**	***p*-Value**	***p*-Value**	***p*-Value**
	***N* (%)**	***N* (%)**	***N* (%)**			
Assisted delivery						
No	1785 (91.8)	1779 (93.2)	2233 (93.4)	0.06	0.05	0.42
Yes	159 (8.2)	130 (6.8)	158 (6.6)			
Missing	115	1230	858			
Preterm birth						
No	1681 (83.3)	2369 (77.5)	2869 (89.2)	<0.01	<0.01	<0.01
Yes	338 (16.7)	686 (22.5)	347 (10.8)			
Missing	40	84	33			
Neonatal jaundice						
No	1239 (61.1)	1685 (61.9)	1897 (69.8)	0.29	<0.01	<0.01
Yes	789 (38.9)	1036 (38.1)	820 (30.2)			
Missing	31	418	532			
Maternal alcohol use						
No	1013 (52.5)	1001 (52.9)	917 (38.6)	0.42	<0.01	<0.01
Yes	916 (47.5)	891 (47.1)	1456 (61.4)			
Missing	130	1247	876			
Maternal anxiety during pregnancy						
No	1846 (91.3)	2484 (92.1)	2547 (94.5)	0.16	<0.01	<0.01
Yes	176 (8.7)	212 (7.9)	147 (5.5)			
Missing	37	443	555			
Pregnancy weight gain recommendations						
Met	653 (35.0)	898 (36.4)	1022 (39.6)	<0.01	<0.01	<0.01
Above	884 (47.3)	1006 (40.7)	1105 (42.8)			
Below	330 (17.7)	565 (22.9)	453 (17.6)			
Missing	192	670	669			

Note: *p*-Values do not include missing categories.

Abbreviations: ASD, autism spectrum disorder; DD, other developmental delay or disability; POP, population comparison.

TABLE 4

Relationship between risk factors and sensory dysfunction among preschool children with autism spectrum disorder and other developmental delays or disabilities in the Study to Explore Early Development Phases 1–3.

	Sensory diagnosis		Unusual sensory interests		Negative response to noise		Idiosyncratic response to certain stimuli	
	ASD	DD	ASD	DD	ASD	DD	ASD	DD
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Preterm birth								
No (REF)								
Yes	1.24	0.91	1.28	0.89	0.77	0.66	0.88	0.58
	(0.92, 1.67)	(0.61, 1.35)	(0.88, 1.87)	(0.59, 1.34)	(0.58, 1.03)	(0.43, 1.01)	(0.67, 1.15)	(0.36, 0.96)
Neonatal jaundice								
No (REF)								
Yes	1.40	1.53	1.08	1.37	1.22	1.50	1.18	1.54
	(1.12, 1.76)	(1.10, 2.11)	(0.83, 1.40)	(0.97, 1.95)	(0.98, 1.52)	(1.04, 2.17)	(0.97, 1.44)	(1.05, 2.28)
Maternal anxiety during pregnancy								
No (REF)								
Yes	1.73	1.88	1.60	1.29	1.49	1.82	1.45	1.80
	(1.22, 2.46)	(1.14, 3.12)	(0.97, 2.62)	(0.70, 2.38)	(1.00, 2.21)	(0.92, 3.58)	(1.05, 2.02)	(0.96, 3.37)
Pregnancy weight gain recommendations								
Met (REF)								
Above	1.15	1.24	1.20	1.52	0.97	1.09	1.02	1.11
	(0.90, 1.47)	(0.87, 1.76)	(0.91, 1.58)	(1.03, 2.23)	(0.77, 1.23)	(0.76, 1.62)	(0.83, 1.26)	(0.72, 1.71)
Below	0.93	1.06	1.15	0.94	0.95	1.11	1.03	1.03
	(0.67, 1.29)	(0.67, 1.69)	(0.79, 1.66)	(0.60, 1.48)	(0.70, 1.29)	(0.69, 1.78)	(0.78, 1.36)	(0.61, 1.73)

Note: Models adjusted for child age, child sex, household income relative to federal poverty threshold, maternal education, maternal race/ethnicity, and early learning composite score.

Abbreviations: aOR, adjusted odds ratio; ASD, autism spectrum disorder; CI, confidence interval; DD, other developmental delay or disability.

TABLE 5

Bivariate correlations between clinical symptoms and sensory dysfunction among preschool children with autism spectrum disorder (above the bold diagonal) and other developmental disabilities (below the bold diagonal) in the Study to Explore Early Development Phases 1–3.

	Sensory diagnosis	Unusual sensory interests	Negative response to noise	Idiosyncratic response to certain stimuli	Adaptive delays	Anxiety problems	Attention deficits/ hyperactivity	Sleep problems
Sensory diagnosis	**1.00**	0.08*	0.08*	0.12*	−0.07	0.16*	0.09*	0.13*
Unusual sensory interests	0.18*	**1.00**	0.08*	0.06	0.12*	0.06*	0.11*	0.11*
Negative response to noise	0.18*	0.23*	**1.00**	0.18*	0.01	0.12*	0.05	0.06
Idiosyncratic response to certain stimuli	0.14*	0.14*	0.30*	**1.00**	0.02	0.19*	0.08*	0.09*
Adaptive delays	−0.05	0.12*	−0.06	−0.07	**1.00**	0.04	0.12*	0.05
Anxiety problems	0.11*	0.15*	0.20*	0.19*	0.05	**1.00**	0.28*	0.35*
Attention deficits/ hyperactivity	0.12*	0.20*	0.09	0.08	0.12*	0.39*	**1.00**	0.30*
Sleep problems	0.10*	0.18*	0.21*	0.16*	0.09*	0.45*	0.34*	**1.00**

* $p < 0.01$; correlations of <0.30 were considered subtle, and correlations ≥0.30 were considered moderate.