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Sensory features in autism: Findings from a large population-based surveillance system

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Abstract

Sensory features (i.e., atypical responses to sensory stimuli) are included in the current diagnostic criteria for autism spectrum disorder. Yet, large population-based studies have not examined these features. This study aimed to determine the prevalence of sensory features among autistic children, and examine associations between sensory features, demographics, and co-occurring problems in other areas. Analysis for this study included a sample comprised of 25,627 four- or eight-year-old autistic children identified through the multistate Autism and Developmental Disabilities Monitoring Network (2006–2014). We calculated the prevalence of sensory features and applied multilevel logistic regression modeling. The majority (74%; 95% confidence interval: 73.5%–74.5%) of the children studied had documented sensory features. In a multivariable model, children who were male and those whose mothers had more years of education had higher odds of documented sensory features. Children from several racial and ethnic minority groups had lower odds of documented sensory features than White, non-Hispanic children. Cognitive problems were not significantly related to sensory features. Problems related to adaptive behavior, emotional states, aggression, attention, fear, motor development, eating, and sleeping were associated with higher odds of having documented sensory features. Results from a large, population-based sample indicate a high prevalence of sensory features in autistic children, as well

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as relationships between sensory features and co-occurring problems. This study also pointed to potential disparities in the identification of sensory features, which should be examined in future research. Disparities should also be considered clinically to avoid reduced access to supports for sensory features and related functional problems.

Lay Summary:

In a large, population-based sample of 25,627 autistic children, 74% had documented differences in how they respond to sensation. We also identified significant associations of sensory features with adaptive behavior and problems in other domains. Sensory features were less common among girls, children of color, and children of mothers with fewer years of education, suggesting potential disparities in identification.

Keywords

autism spectrum disorder; children; epidemiology; logistic models; prevalence; sensory

BACKGROUND

Atypical responses to sensory stimuli, called sensory features, are understood to be highly common in autistic populations (*authors' note: while we acknowledge significant debate in the field* (e.g., Botha et al., 2021), *here we use identity-first language following recent recommendations* (Bottema-Beutel et al., 2020)), and can include over-responsiveness to sensory input (e.g., extreme sensitivity to sounds), diminished responsiveness to sensory input (e.g., no response to pain or touch), and sensory seeking behaviors (e.g., intense focus on parts of an object) (Ausderau et al., 2014; Crane et al., 2009; Jasmin et al., 2009; Leekam et al., 2007; Rogers & Ozonoff, 2005). Sensory features were added to the diagnostic criteria for autism spectrum disorder in the *Diagnostic and Statistical Manual, Fifth Edition* (DSM-5; American Psychiatric Association, 2013), and therefore can now contribute to —but are not required for—receipt of the diagnosis. Existing literature suggests sensory features in 53%–94% of autistic populations (Baranek et al., 2006; Billstedt et al., 2007; Jussila et al., 2020; Klintwall et al., 2011; Leekam et al., 2007; Tomchek & Dunn, 2007), yet these estimates have primarily come from studies that used clinical and convenience samples, limiting their generalizability. The lack of population-based data limits our ability to accurately estimate the prevalence of sensory features in autistic populations, to explore demographic differences, and to understand relevant associations with child characteristics and functioning.

Sensory features are among the earliest observable indicators of autism, with atypical responses to sensation observable within the first year of life (Baranek, 1999; Baranek et al., 2018). In a retrospective video analysis study, Baranek (1999) identified unique patterns of differential sensory response at 12 months of age, including diminished responses (e.g., visual orienting and response to name-call), over-responsiveness (e.g., aversion to touch), and sensory seeking (e.g., excessive mouthing of objects). More recent research provides further evidence of early sensory seeking and reduced orienting among autistic children, as well as among younger siblings who have a greater likelihood of autism diagnosis (Baranek et al., 2018; Damiano-Goodwin et al., 2018). The available evidence suggests autistic people who display sensory features present with them in early childhood and continue through adolescence and adulthood (Ben-Sasson et al., 2007; Crane et al., 2009; Wiggins et al., 2009). However, there is varying evidence as to what extent sensory features remain stable over time (Baranek et al., 2019; Ben-Sasson et al., 2009, 2019; McCormick et al., 2016).

Interdisciplinary perspectives suggest a relationship between sensory functioning and "cascading effects" on child development (Baranek et al., 2018; Brandwein et al., 2015; Cascio et al., 2016). For instance, children who are extremely focused on or overwhelmed by sensory aspects of the environment may have more difficulty engaging in activities that promote cognitive, adaptive, motor, and social development. These effects may have long-term impacts on autistic individuals' abilities to engage and participate in meaningful activities in life (Cascio et al., 2016). Accordingly, evidence points to associations between sensory features and problems in other areas such as attention, mood, and anxiety (Dellapiazza et al., 2018; Feldman et al., 2020; Green et al., 2012), as well as with critical daily activities including sleeping and eating (Mazurek et al., 2013; Mazurek & Petroski, 2015; Thomas et al., 2015). Studies of family routines illustrate how some daily activities can be stressful for autistic children due to sensory features (e.g., over-responsiveness to food tastes and textures, extreme sensitivity to noise) (Bagby et al., 2012; Schaaf et al., 2011).

Existing literature shows associations between cognition and sensory features, with lower cognitive scores associated with greater sensory features (Ben-Sasson et al., 2019). Several studies also found associations between sensory features and adaptive behavior levels, with patterns of lower adaptive behavior scores in the presence of increased sensory features, even when accounting for cognition (Jasmin et al., 2009; Lane et al., 2010; Liss et al., 2006; Rogers et al., 2003; Tomchek et al., 2015; Watson et al., 2011; Williams et al., 2018). However, there is some variation in longitudinal results examining the relationship between early sensory features and later adaptive behavior challenges—with one study finding a significant positive association for autistic children (Williams et al., 2018) and another finding no association (McCormick et al., 2016).

Knowledge about the ways that sensory features relate to functioning for autistic children can inform sensory evaluation and treatment recommendations. Yet, there is a dearth of population-based evidence to inform clinical recommendations and future research on this topic. In the current study, we used surveillance data from the multistate Autism and Developmental Disabilities Monitoring (ADDM) Network to examine the prevalence of sensory features among 4- and 8-year-old autistic children, as well as associations with demographic factors and challenges across various domains among a large, population-based sample of autistic children.

METHODS

This cross-sectional analysis utilized ADDM Network data. Approval was granted by individual project site institutional review boards.

Data source

The ADDM Network is a population-based ongoing records-based surveillance system for autism and other developmental disabilities that was started in 2000 and is overseen by the US Centers for Disease Control and Prevention (CDC). ADDM conducts surveillance on even years and includes multiple sites in the United States (site inclusion varies by surveillance year). Each site examined health records, and most sites also examined educational records from children receiving special education services, to identify children meeting the ADDM surveillance case definition for autism spectrum disorder. The ADDM case definition was based on DSM-IV or DSM-5 criteria (depending on the surveillance year), and determined by clinician review (Baio et al., 2012, 2014, 2018; Christensen et al., 2018; Rice et al., 2009). Each year the surveillance focused on 8-year-old children living in ADDM catchment areas, and beginning in 2010 included 4-year-old children as well. All sites adhere to a common protocol for record review and abstraction, overseen by the CDC. Additional information about ADDM procedures is available in prior publications (Baio et al., 2012, 2014, 2018; Christensen et al., 2018; Maenner et al., 2016; Rice et al., 2009; Wiggins et al., 2012).

Sample

The sample for the present analyses included 8-year-old autistic children from five sequential surveillance years (2006, 2008, 2010, 2012, and 2014) representing data from 16 sites (select catchment areas in AL, AR, AZ, CO, FL, GA, MD, MN, MO, NC, NJ, PA, SC, TN, UT, and WI), as well as 4-year-old autistic children from three surveillance years (2010, 2012, and 2014) from seven sites (AZ, CO, MO, NC, NJ, UT, and WI). Different combinations of sites participated in each surveillance year (not every included site was involved in every included year). Five autistic children with missing data on sensory features (0.02%) were excluded from the sample. The final sample included 25,627 autistic children (2913 from 4-year-old surveillance and 22,714 from 8-year-old surveillance). The majority (81.8%) of the children were male (additional sample description in Table 1).

Variables

Demographic information—We included several demographic variables in the analyses: child sex, child race and ethnicity, and maternal education level during pregnancy (selected as a proxy for socioeconomic status/early childhood service access (Crosnoe et al., 2021)). We also included whether the child's data were collected as part of the 4-year-old or 8-year-old surveillance.

Functional measures—A cognitive functioning estimate and an adaptive behavior estimate were documented from the child's most recent cognitive and adaptive behavior tests during or before the surveillance year, when available. A wide range of standardized assessments were accepted for ADDM surveillance (Patrick et al., 2021). The most common cognitive assessments included as the most recent test for the children in this sample were the Wechsler Intelligence Scale for Children (20.7%) and the Differential Ability Scales (15.8%). The most common adaptive behavior tests were the Vineland Adaptive Behavior Scales (59.7%) and the Adaptive Behavior Assessment System (21.4%). Each was coded into a binary variable representing a standard score >70 (representing scores within two standard deviations of the mean, or higher) or ≤70 (representing scores less than or equal to two standard deviations below the mean). This cutoff is consistent with prior CDC reports, wherein a cognitive standard score ≤70 represents intellectual disability (Baio et al., 2014, 2012, 2018; Christensen et al., 2018; Rice et al., 2009).

Sensory features—The ADDM Network collects data on various characteristics common in autistic children. These "autism feature" variables were documented as binary—indicating either presence or absence of the specified characteristic anywhere in the child's records, as recorded by trained clinician reviewers. For this analysis, we used ADDM's sensory autism feature variable, defined as "odd responses to sensory stimuli." This variable captured a range of atypical sensory reactions including sensitivity or exaggerated reactions (e.g., high sensitivity to sound), diminished reactions (e.g., decreased reaction to temperature), and fascination or increased attention (e.g., smelling objects, staring at lights) to sensory stimuli.

Co-occurring challenges—Other "autism feature" variables we included in the analysis were problems related to emotional states, aggression, motor development, hyperactivity/attention, fear (either lack of, or excessive), sleep, and eating or drinking. As with sensory features, these were documented as binary (presence or absence).

Data analysis

We used R (Version 4.0.3, R Foundation for Statistical Computing) for data management and analyses. To examine the prevalence of sensory features across all included years and sites, we calculated the total percentage of the autism sample with reported sensory features and 95% confidence interval (CI; estimated as a one-sample proportions test with continuity correction) across all included years and sites; we also calculated prevalence for 4- and 8-year-olds separately.

We used the mlogit package and glmer function in R to conduct multilevel logistic regression analyses, accounting for clustering by site and surveillance year * site (random effects). First, we conducted multilevel univariate analyses to examine associations between sensory features and each of the other study variables, while accounting for clustering. We then conducted multivariable multilevel logistic regression analyses to assess associations between the presence of sensory features with the demographic (i.e., surveillance age, sex, race/ethnicity, and mother's education), autism feature (i.e., co-occurring challenges in the areas of emotional states, aggression, motor development, hyperactivity/attention, fear [lack of, or excessive], eating/drinking, and sleeping), and functional variables (i.e., cognition, adaptive behavior) in a combined model, while accounting for clustering.

Children were missing data for several variables including race/ethnicity (2.7%), maternal education (32.7%), cognitive score (25.8%), and adaptive behavior score (45.0%) (see Table 1). We compared the children with complete data to those with missing data on the demographic variables using χ^2 tests, revealing slight but significant differences on surveillance age and race/ethnicity (see Table S1). Due to the high levels of missingness, we retained the full sample size for analyses, including children with missing data as an additional categorical level for each of these variables. We examined variance inflation factors for the multivariable model and identified no multicollinearity.

Due to the 2013 release of the DSM-5—and its inclusion of sensory features as a diagnostic criteria—some children in the 2014 surveillance year may have had more likelihood to have documented sensory features in their records. Although we do account for study year in the analyses, we also re-ran our final regression model removing the 2014 participants as an additional robustness check.

RESULTS

The prevalence of sensory features in the full sample was 74.0% (95% CI: 73.5%–74.5%). Among children surveilled at ages 4 and 8 years, the prevalence of sensory features was 70.1% (95% CI: 68.4%–71.7%) and 74.5% (95% CI: 73.9%–75.1%), respectively, revealing a slightly higher unadjusted prevalence in children studied at the older age.

With the exception of surveillance age and cognitive score, all other studied variables had a statistically significant univariate relationship with sensory features (see Table 1). In the multivariable multilevel logistic regression model, the variance (standard deviation) for the random effects of site were 0.02(0.14), and for surveillance year * site were 0.13(0.36). See Table 1 for full results of the fixed effects. In the model, male children had 1.20 (95% CI: 1.11–1.30) times greater odds than female children to have documented sensory features. Compared to White, non-Hispanic children, we observed a significantly lower odds of documented sensory features for Black, non-Hispanic children (odds ratio [OR]: 0.71; 95% CI: 0.66–0.78), Asian or Pacific Islander, non-Hispanic children (OR: 0.78; 95% CI: 0.66–0.92), and Hispanic children (OR: 0.76; 95% CI: 0.69–0.83). Children of mothers with more than 12 years of education had significantly higher odds of documented sensory features than those with fewer than 12 years of education. Adaptive behavior challenges were associated with sensory features; children with below-average scores had 1.11 (95% CI: 1.01–1.21) times the odds of demonstrated sensory features than children with higher adaptive behavior scores. Other co-occurring challenges we examined were all significantly and positively associated with sensory features, including problems related to emotional states, aggression, motor development, hyperactivity/attention, fear (lack of, or excessive), sleep, and eating or drinking. Consistent with the univariate model, cognitive problems were not significantly associated with odds of sensory features in the multivariable model. In contrast with the unadjusted results demonstrating higher rates of sensory features among 8-year old children, and non-significance in the univariate model, the multilevel multivariable model revealed significantly lower odds of sensory features among the 8-year old surveillance group.

In both the univariate and multivariable models, children with missing data on race/ethnicity did not have significantly different odds of sensory features than White, non-Hispanic children. However, those with missing data on mother's education, cognition, and adaptive behavior did have significantly different odds of sensory features than the reference groups. Specifically, in the multivariable model, those without mother's education data had 1.43 (95% CI: 1.27–1.61) times the odds of documented sensory features than those with less than 12 years of education, similar to children with mothers with more years of education. For both cognitive and adaptive behavior scores in the multivariable model, children without these assessments in their records were significantly less likely to have documented sensory features, with odds of 0.83 (95% CI: 0.76–0.90) and 0.90 (95% CI: 0.82–0.98), respectively.

When the multivariable model was repeated with 2014 removed (see Table S2), the results remained highly consistent with the exception of the Asian or Pacific Islander, non-Hispanic group no longer being significantly different than the White, non-Hispanic group (likely due to small sample size).

DISCUSSION

Almost three-quarters of 4- and 8-year-old children in the ADDM Network had documented sensory features, within the 53%–94% range observed in prior research with samples of autistic children (Ausderau et al., 2014; Baranek et al., 2006; Billstedt et al., 2007; Crane et al., 2009; Jussila et al., 2020; Klintwall et al., 2011; Leekam et al., 2007; Tomchek & Dunn, 2007). These findings highlight the need for early screening of sensory concerns to guide treatment referrals. Most early screening tools (Hyman et al., 2020) include sensory-related questions, including the most commonly used tool for toddler autism screening, the Modified Checklist for Autism in Toddlers (Robins et al., 2014). Some early screening tools also include sensory subscales, such as the First Year Inventory (Watson et al., 2007), which may offer more thorough information about sensory features in young children. For older children and adults, there are also autism screening tools that include items related to sensory features (Thabtah & Peebles, 2019). Occupational therapists are trained in sensory assessments and treatments, and can provide services to support autistic children to more successfully participate in their daily activities (Schoen et al., 2019).

Prior evidence indicates sensory features impact the everyday lives of autistic children and their families, with cascading effects theorized to impact daily living, educational, and mental health outcomes (Cascio et al., 2016). Adaptive behavior challenges and other problems such as attention, and internalizing and externalizing behaviors have shown associations with sensory features in previous work. Consistent with existing studies (e.g., Dellapiazza et al., 2018; Feldman et al., 2020; Green et al., 2012; Mazurek et al., 2013; Thomas et al., 2015; Tzischinsky et al., 2018), we identified that problems in areas of adaptive behavior, motor development, attention, emotional states, hyperactivity, fear, sleeping, and eating were associated with increased odds of sensory features. These findings offer further support for the theorized relationships between sensory features and other areas of life for autistic children (Cascio et al., 2016).

Notably, we did not identify associations between cognitive measures and sensory features, despite prior work finding a relationship with sensation seeking in particular (Ben-Sasson et al., 2019). Interestingly, Ben-Sasson et al. found no significant relationship between cognition and either of the other two sensory patterns investigated (e.g., sensory over-responsivity and sensory under-responsivity). The current findings reinforce the idea that sensory features may be a unique factor in autism profiles, separate from cognitive ability. Finally, despite our results demonstrating statistically significant relationships on several variables, it is important to acknowledge that sensory features were quite prevalent across the sample, even among children without documented problems in other areas. This implies that sensory features are a prominent feature for most autistic children, regardless of other factors.

If and how sensory features change across development have not been well established. Consistent with the findings from Ben-Sasson et al.'s (2009, 2019) two meta-analyses we found a slightly increased rate of sensory features in the 8- versus 4-year-old surveillance datasets. However, we found the opposite pattern when modeled hierarchically in a multivariable model. The differences observed in the raw numbers could be an artifact of the increased opportunities children had over 8 years of life to have sensory features documented by healthcare and/or educational providers, and/or related to missing data. Prior longitudinal studies have noted some declines over time, but overall consistency in the presence of sensory features during childhood (Baranek et al., 2018, 2019; McCormick et al., 2016; Perez Repetto et al., 2017). Studies including autistic adults also indicate that sensory features persist into adulthood, and impact meaningful participation in activities (Crane et al., 2009; Kern et al., 2006; Leekam et al., 2007). In the current study, we only had access to cross-sectional data from record reviews of 4- and 8-year-old children. Future work is needed to understand age-related changes in sensory features, and the impact of development over time, for autistic people across the lifespan.

While this study offers a large-scale overview of associations with sensory features, it also provides insight into potential disparities in the identification of sensory features. We found that children who were male, White, non-Hispanic, and had a more highly educated mother at birth were significantly more likely to have sensory features documented in their records. Given existing evidence about disparities in autism (Yuan et al., 2021), we expect these are disparities in identification and possibly in access to specialized services such as occupational therapy that can address sensory features (Cascio et al., 2016). For example, it is possible that similar behaviors may be documented differently for different children by clinicians and educators (e.g., sensory features misidentified as problem behavior among Black children; Meek & Gilliam, 2016; Obeid et al., 2020) and/or go unidentified (e.g., different clinician expectations or different presentation in female children; Halladay et al., 2015). More research is needed to uncover potential biases and structural barriers that may limit the identification of sensory features in autistic girls and children from diverse backgrounds, as well as to improve access to services that may help mitigate potential long-term challenges. The identified sex differences in sensory features should also be explored in the emerging research examining autism in girls, and the complex intersections of biological and sociocultural factors (e.g., Harrop et al., 2021).

Limitations

A primary limitation of this study is the focus on a single, binary sensory variable rather than a robust validated tool, such as the Sensory Profile (Dunn, 1999; see Burns et al., 2017 and DuBois et al., 2017 for relevant reviews of available sensory measures). Prior studies using such tools have established differential associations with unique aspects of sensory features (e.g., over-responsivity, under-responsivity, and sensory seeking). Further, since the variable was documented based upon record review rather than through standardized direct assessment, absence of the documentation did not necessarily equate to absence of the feature. ADDM Network methodology involved review of a child's evaluations documented throughout their development (up to the surveillance year), providing the opportunity to consider a child's complete record; however, by design, data collected were dependent on myriad factors. It is possible that some children may have had less complete records, and thus fewer opportunities to have sensory features and other examined variables documented in their records. To check the possibility of this phenomenon, we examined the dataset posthoc and found that over 99% of the sample had at least one autism feature variable endorsed, and the few children without any autism feature variables endorsed had available cognitive data. Therefore, we do believe there was sufficient opportunity for all children in the sample to have sensory features documented in their included records. Further, it is important to note that we were not able to infer causality using the available cross-sectional data.

Another notable limitation is the high levels of missing data on certain included variables, introducing the potential for bias. In particular, mother's education level, cognitive assessment, and adaptive behavior assessment data were missing in a sizable proportion of the sample. We observed that children without cognitive scores and children without adaptive behavior scores were significantly less likely to have recorded sensory features in their records than children with both high and low scores on these measures. It is possible that these children did not present any potential problems in the areas of adaptive behavior or cognition (thus not warranting assessment), and that this corresponds with a decreased likelihood of sensory features. However, the lack of these assessments could also signal decreased exposure to service providers who could be more likely to recognize and document sensory-related concerns. Further research is needed to understand these relationships.

Finally, our results regarding potential disparities in the identification of sensory features (e.g., among children of color and female children) also have implications for our prevalence findings; if there was under-identification of sensory features in some groups, then the true prevalence of sensory features could potentially be higher than reported here.

CONCLUSION

The current study using ADDM Network data identified that approximately three-quarters of 4- and 8-year-old autistic children demonstrate sensory features. We identified statistically significant relationships with several other characteristics demonstrating that challenges in the areas of adaptive behavior, emotional states, hyperactivity, motor development, aggression, fear, sleeping, and eating are associated with the presence of sensory features. Our findings also revealed potential sociodemographic disparities that warrant further investigation of potential biases and/or structural barriers to the identification and treatment of sensory features.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Autism and Developmental Disabilities Monitoring (ADDM) Network (2006–2014) sample characteristics of 4-and 8-year-old autistic children, cross-tabulated proportions with sensory features, and results from univariate and multivariable logistic regression models (dependent variable: sensory features) ($N = 25,627$)

	Sample description number (percent)	Proportion with sensory features percent	Univariate logistic regression[a] OR (95% CI)	Multivariable logistic regression[a] OR (95% CI)
Sensory feature variable[b]				
Sensory features	18,968 (74.0)			
No sensory features	6659 (26.0)			
Age of cohort				
4 years old	2913 (11.4)	70.1	Reference	Reference
8 years old	22,714 (88.6)	74.5	1.07 (0.97–1.17)	**0.86 (0.78–0.96)**
Sex				
Female	4672 (18.2)	71.8	Reference	Reference
Male	20,954 (81.8)	74.5	**1.17 (1.08–1.25)**	**1.20 (1.11–1.30)**
Missing	1 (<0.1)			
Race/ethnicity[c]				
White, NH	14,071 (54.9)	77.8	Reference	Reference
Black, NH	5144 (20.1)	68.2	**0.63 (0.58–0.68)**	**0.71 (0.66–0.78)**
American Indian or Alaska native, NH	136 (0.5)	71.3	**0.64 (0.44–0.93)**	0.71 (0.47–1.07)
Asian or Pacific Islander, NH	919 (3.6)	71.9	**0.70 (0.60–0.82)**	**0.78 (0.66–0.92)**
Other race, NH	747 (2.9)	75.2	**0.81 (0.68–0.97)**	0.86 (0.71–1.04)
Hispanic (any race)	3924 (15.3)	68.7	**0.64 (0.59–0.70)**	**0.76 (0.69–0.83)**
Missing	686 (2.7)	71.3	0.90 (0.76–1.08)	1.15 (0.94–1.40)
Mother's education				
<12 years	2259 (8.8)	67.1	Reference	Reference
12 years	4785 (18.7)	70.5	**1.20 (1.08–1.34)**	**1.17 (1.04–1.32)**
13–15 years	4209 (16.4)	74.3	**1.48 (1.32–1.66)**	**1.47 (1.30–1.67)**
16 years	3722 (14.5)	77.3	**1.75 (1.55–1.97)**	**1.69 (1.48–1.93)**
>16 years	2275 (8.9)	79.9	**2.06 (1.79–2.37)**	**2.03 (1.74–2.37)**
Missing	8377 (32.7)	74.7	**1.42 (1.28–1.59)**	**1.43 (1.27–1.61)**

	Sample description number (percent)	Proportion with sensory features percent	Univariate logistic regression[a] OR (95% CI)	Multivariable logistic regression[a] OR (95% CI)
Cognition				
SS > 70	12,493 (48.7)	76.9	Reference	Reference
SS ≤ 70	6534 (25.5)	77.1	1.06 (0.99–1.14)	1.01 (0.93–1.10)
Missing	6600 (25.8)	65.5	**0.60 (0.56–0.65)**	**0.83 (0.76–0.90)**
Adaptive behavior				
SS > 70	6625 (25.9)	77.2	Reference	Reference
SS ≤ 70	7464 (29.1)	79.6	**1.19 (1.10–1.30)**	**1.11 (1.01–1.21)**
Missing	11,538 (45.0)	68.6	**0.68 (0.63–0.73)**	**0.90 (0.82–0.98)**
Emotional states				
No mood or affect problems	5849 (22.8)	59.7	Reference	Reference
Mood or affect problems	19,778 (77.2)	78.3	**2.18 (2.04–2.32)**	**1.41 (1.31–1.51)**
Aggression				
No aggression problems	12,175 (47.5)	68.3	Reference	Reference
Aggression problems	13,452 (52.5)	79.2	**1.72 (1.62–1.82)**	**1.19 (1.11–1.27)**
Motor				
No motor delay problems	6978 (27.2)	56.9	Reference	Reference
Motor delay problems	18,649 (72.8)	80.4	**2.99 (2.81–3.18)**	**2.16 (2.02–2.31)**
Hyperactivity/attention				
No hyperactivity or attention problems	3254 (12.7)	54.9	Reference	Reference
Hyperactivity or attention problems	22,373 (87.3)	76.8	**2.62 (2.42–2.84)**	**1.67 (1.53–1.82)**
Fear (lack of, or excessive)				
No problems in lack of/excessive fear	14,097 (55.0)	65.2	Reference	Reference
Problems in lack of/excessive fear	11,530 (45.0)	84.8	**2.74 (2.57–2.92)**	**1.99 (1.85–2.13)**
Sleep				
No sleep problems	16,693 (65.1)	68.9	Reference	Reference
Sleep problems	8934 (34.9)	83.5	**2.12 (1.99–2.27)**	**1.36 (1.27–1.47)**
Eating/drinking				
No eating/drinking problems	11,434 (44.6)	62.5	Reference	Reference
Eating/drinking problems	14,193 (55.4)	83.3	**2.84 (2.68–3.02)**	**2.10 (1.97–2.24)**

Note: SSs >70 represent scores within two standard deviations of the mean or higher, SSs ≤70 represent scores less than or equal to two standard deviations below the mean. Bolded results are significant at $\alpha = 0.05$ level.

Abbreviations: CI, confidence interval; NH, non-Hispanic; OR, odds ratio; SS, standard score.

[a]The logistic regressions to test the univariate and multivariate associations with sensory features were fit as multilevel models with site and surveillance year * site as random effects.

[b]The sensory features variable indicates documentation of the presence of any atypical sensory behaviors in a single ADDM variable (further defined in the text), proportions were suppressed for cell sizes <5.

[c]Race/ethnicity groups are coded as mutually exclusive.