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Sensory Reactivity at 1 and 2 years old is Associated with ASD Severity During the Preschool Years

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Abstract

Children with Autism Spectrum Disorder (ASD) often display atypical sensory reactivity within the first years of life, prior to a diagnosis. This study examined sensory reactivity patterns at 14 months, changes from 14 to 23 months, and later ASD severity at 3 to 5 years of age in children (n=87) at elevated likelihood of ASD. Results indicated that observed hyporeactivity at 14 months and increases from 14 to 23 months were related to higher ASD severity during the preschool

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years. Parent report of hyperreactivity at 14 months was associated with higher ASD severity in the RRB domain during the preschool years. Early hypo and hyperreactivity may predict later severity of ASD and aid in subtyping and developing individualized treatments.

Keywords

Autism; Autism Spectrum Disorder; Sensory; Toddlers; Severity

Studies estimate that 70-90% of children with Autism Spectrum Disorder (ASD) display atypical reactivity to sensory stimuli (Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson et al., 2009; Leekam, Nieto, Libby, Wing, & Gould, 2007). This atypical reactivity is often characterized into three types that regularly co-exist in individuals with ASD: hyporeactivity (decreased or no reaction to sensory stimuli when it would be expected), hyperreactivity (increased or aversive reaction to sensory stimuli), and sensory seeking (behaviors that intensify or extend sensory experiences) (Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson et al., 2008; 2009; Schneider et al., 2008). Hyporeactivity has most consistently been reported in young children with or at-risk for ASD (Baranek, David, Poe, Stone, & Watson, 2006; Baranek et al., 2013; Ben-Sasson et al., 2007; 2009), though hyperreactivity and sensory seeking are also regularly reported (Baranek, 1999a; Baranek et al., 2018; Ben-Sasson et al., 2008; 2013; Freuler, Baranek, Watson, Boyd, & Bulluck, 2010; Green, Ben-Sasson, Soto, & Carter, 2012; Wolff et al., 2019). Closer examinations of the nuances of these hypo-, hyper-, and seeking reactivity patterns in even more detail has suggested that certain aspects of auditory processing, lower registration, or modality sensitivities (e.g., tactile, oral, touch) may influence these atypical reactivity patterns (Donkers et al., 2015; Germani et al., 2014; Philpott-Robinson et al., 2016; Rogers, Hepburn, & Wehner, 2003; Wiggins et al., 2009). However, more work is required to understand the specific mechanisms of atypical sensory response patterns.

In several prospective studies, atypical sensory reactivity has been found in infants and toddlers at elevated likelihood for developing ASD, suggesting a potential precursor to an ASD diagnosis. For example, parents reported sensory differences as young as 6 months of age in infant siblings of children with ASD who later met criteria for an ASD diagnosis (Sacrey et al., 2015). In another infant sibling study, 12-month-old children later diagnosed with ASD showed elevated hyperreactivity compared to children who do not develop ASD (Wolff et al., 2019). By 24 months, infant siblings who received diagnoses of ASD showed significant elevations across hyporeactivity, hyperreactivity, and sensory seeking behaviors (Wolff et al., 2019). In a community sample of 12-month-old infants, the domain of sensory reactivity and regulatory functions, as reported by parents, was found to be a specific predictor of a later diagnosis of ASD (Turner-Brown, Baranek, Reznick, Watson, & Crais, 2013).

Some researchers have suggested that early sensory atypicalities may lead to later social deficits associated with ASD (Hannant, Tavassoli, & Cassidy, 2016) such that atypical sensory reactivity may have a “developmental cascading effect” on later social communication skills (Baranek et al., 2018). For example, one study of toddlers with ASD

found a relationship between high sensory hyperreactivity and increased social approach behaviors, suggesting that increased hyperreactivity may, in some instances, be a marker of resilience or even an indicator of a child's ability to optimally benefit from socially supportive environments (Jones, Dawson, & Webb, 2018). A similar, though not statistically significant, trend was also reported in an earlier study (Watson et al., 2011).

Research also indicates that patterns of change in sensory reactivity during the second year of life may be particularly relevant for a later ASD diagnosis. For example, children later diagnosed with ASD showed significant increases in hyporeactivity and hyperreactivity from 12 to 24 months (Wolff et al., 2019). Sensory seeking behaviors have also been found to increase over the second year of life in children with ASD and may be related to less social orienting and attention disengagement (Baranek et al., 2018). These results have been seen in both community-ascertained samples (Baranek et al., 2018) as well as in children at elevated likelihood for developing ASD due to having an older sibling with ASD (Damiano-Goodwin et al., 2018), highlighting the consistency of these behaviors across children with potentially different ASD etiology.

While there is growing research supporting the relationship between early sensory reactivity and later ASD diagnoses (Bizzell, Ross, Rosenthal, Dumont, & Schaff, 2019; Germani et al., 2014; Turner-Brown et al., 2013; Wolff et al., 2019), this relationship merits further systematic study (Baranek et al., 2018), since different types of sensory patterns may be related to different neurobiological underpinnings or be suggestive of different phenotypic or adaptive presentations and outcomes (Ausderau et al., 2016; Baranek, Watson, Boyd, Poe, David, & McGuire, 2013; Damiano-Goodwin et al., 2018; Jones et al., 2018; Watson et al., 2011; Williams et al., 2018). Further, understanding the relationship between sensory reactivity patterns at 1 and 2 years old and later ASD severity may have implications for early identification and treatment planning. The objective of this study is to evaluate the association between sensory reactivity (hyporeactivity, hyperreactivity, and sensory seeking) at 14 months and ASD symptom severity during the preschool years. In addition, the association between changes in sensory reactivity from 14 to 23 months and later ASD severity will be examined. Our primary measure of interest was a direct observation measure of sensory reactivity, decreasing potential bias associated with parent report. However, recognizing the utility of parent report measures, we replicated analyses using a parent report questionnaire of sensory reactivity. Based on previous literature, we hypothesize that higher hyporeactivity, hyperreactivity, and sensory seeking behaviors at 14 months, as well as increases in these sensory behaviors from 14 to 23 months, will be associated with higher severity of ASD symptoms during the preschool years.

Methods

Participants.

Eighty-seven children (60 males) and their caregivers participated in this study as part of an early intervention trial (see Watson et al., 2017). Children were eligible for the study if scores on the First Year Inventory 2.0 (FYI 2.0; Baranek, Watson, Crais, Reznick, 2003) at 12 months of age indicated elevated likelihood for developing ASD (risk scores above cut-off). All caregivers included in the study completed written informed consent as approved by

the Institutional Review Board (IRB). Additional eligibility criteria included birthweight >2500g and English spoken as a primary language at home.

All children completed an initial assessment at 14 months (± 0.77 ; Time 1). The majority of children were White ($n=60$; 70%; race not reported for one child) and the education level of parents was largely a four-year college degree or higher ($n=58$; 67%). Forty-five (52%) of the children were randomized to an intervention (Adapted Responsive Teaching; ART) while the remainder were assigned to a “Referral to Early Intervention and Monitoring” group (REIM). See Watson et al., 2017 for details of treatment groups. Of the 87 children initially enrolled in the study, 83 returned for a follow-up assessment at 23 months of age (± 0.86 ; Time 2). Families were later contacted when their children were between 3 and 5 years old (mean = 54 months $\pm$ 11 months; Time 3) for a follow-up diagnostic evaluation, of which 49 returned for an in-person assessment and 45 completed the ADOS-2 (19 from the REIM group and 26 from the ART group). Of the 45 children who completed ADOS assessments, 13 received an ASD diagnosis, 7 received non-ASD developmental delay or other diagnosis, a diagnosis was not determined for 1 child, and the remaining children ($n=24$) did not receive any diagnosis. See Table 1 for background and demographic information.

Measures.

Cognitive.—Children were administered the Mullen Scales of Early Learning (MSEL; Mullen, 1995) as a descriptive measure of cognitive abilities at Time 1 and Time 2. The MSEL yields standard scores (T-scores) in the domains of fine motor, visual reception, receptive language, and expressive language. The T-Score from the Visual Reception Domain at Time 1 was included as a covariate in analyses (see below). See Table 1 for MSEL information at Time 1 and Time 2.

Sensory Reactivity.—The Sensory Processing Assessment for Young Children (SPA; Baranek, 1999; Baranek et al., 2007, 2013) is a direct assessment of a child’s sensory reactivity to a variety of stimuli. The SPA is a 15-minute play-based observational measure designed for children between 6 months and 9 years of age. Results of the SPA yield information about the child’s hyporeactivity (i.e., decreased responsiveness to auditory, visual and tactile stimuli), hyperreactivity (i.e., increased responsiveness to auditory, visual and tactile stimuli), and sensory seeking behaviors (i.e., intense craving, repetition or fascination of sensory experiences with objects or body). The SPA has been found to be psychometrically valid, with high inter-rater reliability and strong convergent validity with other measures of sensory processing (Baranek et al., 2007, 2013). The SPA was administered to children at Time 1 and Time 2.

The Sensory Experiences Questionnaire Version 2.1 (SEQ; Baranek, 1999b; Baranek et al., 2006; Little et al., 2011) is a 15-minute, 43-item parent questionnaire about children’s reactions to sensory stimuli in everyday situations. It has been used with young children, both typically and atypically developing, between 5 months and 12 years of age (Baranek, David, Poe, Stone, & Watson, 2006; Baranek et al., 2013; Kirby et al., 2019). Caregiver responses to the SEQ items are rated on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always), with higher scores indicating more sensory symptoms. Higher scores

on the SEQ indicate more sensory symptoms. As a companion to the SPA, the SEQ similarly yields scores on three constructs: hyporeactivity, hyperreactivity, and sensory seeking behaviors, across modalities. The SEQ also has high test-retest reliability (Little et al., 2011) and internal consistency (Baranek, David, Poe, Stone, & Watson, 2006). The parents completed the SEQ about their child at Time 1 and Time 2. The domains of hyporeactivity, hyperreactivity, and sensory seeking behaviors were analyzed as a replication to the SPA analyses.

ASD Severity.—The Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012) was completed with 45 of 49 children who returned for Time 3 in-person assessments. (The ADOS could not be completed with four children seen for follow-up due to challenging behaviors of children or time constraints of caregivers.) The ADOS-2, a gold standard diagnostic tool, obtains information about ASD symptoms through direct observation by a trained clinician. A research reliable clinician administered or directly supervised ADOS-2 assessments. Two children received ADOS-2 Module 1, for individuals with no or few words, 22 received ADOS-2 Module 2, for individuals with phrase speech, and 21 received Module 3, for individuals with complex speech. The ADOS-2 yields an overall calibrated severity score (CSS; Gotham, Pickles, & Lord, 2009) as well as separate calibrated severity scores for the social affect domain (CSS-SA) and the restricted, repetitive behavior domain (CSS-RRB; Hus, Gotham, & Lord, 2014).

Data Analysis.—To account for missing data, particularly ADOS-2 data at Time 3, multiple imputation was carried out using Multivariate Imputation by Chained Equations (see MICE package in R; R Core Team, 2018; van Buuren & Groothuis-Oudshoorn, 2011). All missing variables were imputed simultaneously. For each continuous missing variable, the imputation model for the missing value was a linear regression model with all of the other variables in the dataset as covariates. For categorical variables, a multinomial logistic regression model was used instead. Missing values were assumed to be missing at random (MAR), i.e., the likelihood that the data is missing is independent of the missing data's values conditional on the observed variables in the imputation model. This is a weaker assumption than missing completely at random (MCAR), in which the likelihood that the data is missing is independent of the missing data's values without having to condition on the observed variables in the model. Multiple imputation provides valid statistical inference under MAR while other methods, such as listwise or pairwise deletion, do not (e.g., Little & Rubin, 2002); thus, the stronger MCAR assumption was unnecessary. Due to the inclusion of SPA/SEQ domains at Times 1 and 2, treatment group, age at all time points, and MSEL Visual Reception T-Score at Time 1 in the imputation models, MAR was deemed reasonable. Furthermore, the plausibility of the imputed values was checked by a series of colored scatterplots (see Supplementary Figure 1), plotted with observed values in blue and imputed values in red. A total of 50 imputed datasets were generated in this manner, per recommendations from White et al. (2010). Multiple imputation has been shown to be statistically valid when both the dependent variables and outcome variable have missing values (Rubin, 2004; Gellman, 2012). The results from each imputed model (estimates and standard errors) were aggregated using Rubin's rules (Rubin 2004).

Next, linear regression models were fitted to each imputed dataset with ADOS score at Time 3 as the outcome and SPA domain score at Time 1 and the change in each SPA domain score from Time 1 to Time 2 as independent variables. A separate model was fit for each set of ADOS score types (i.e., total CSS, CSS-SA, and CSS-RRB) and SPA domains (hyperreactivity, hyporeactivity, sensory seeking). Treatment group (ART and REIM) and age at Time 3 were included as covariates in all analyses. Given previous work noting a relationship between developmental level and sensory reactivity patterns (Baranek et al., 2007, 2013), we also included MSEL Visual Reception T-Score at Time 1 as a covariate in analyses. For continuous predictors, semi-partial correlations were calculated using the mean semi-partial correlation across the imputed datasets to provide information about size of the effect. For group, an adjusted Cohen's *d* was calculated to provide information about size of the effect (Lipsey and Wilson, 2001). Analyses were replicated using the SEQ.

Results

The covariates (age at Time 3, treatment group, Visual Reception score on the MSEL at Time 1) were not statistically significant at the $\alpha < 0.05$ level in any of the regression models (hyporeactivity, hyperreactivity, or sensory seeking). Analyses were also run to include a treatment group by SPA/SEQ interaction to further assess if treatment group differentially impacted SPA/SEQ and later autism symptoms; the results were not statistically significant (confidence intervals all include 0).

Primary Analyses: SPA.

Hyporeactivity.—At Time 1, SPA Hyporeactivity was significantly associated with ADOS CSS-SA at Time 3 [95% CI (0.02, 2.46); semi-partial correlation = 0.29]. Increases in SPA Hyporeactivity from Time 1 to Time 2 were also significantly related to higher ADOS CSS-RRB [95% CI (0.00, 2.30); semi-partial correlation = 0.26] and ADOS CSS-SA [95% CI (0.15, 2.19); semi-partial correlation = 0.31], See Figure 1.

Hyperreactivity.—SPA Hyperreactivity at Time 1 and changes from Time 1 to Time 2 were not significantly related to ADOS CSS-RRB [semi-partial correlations = 0.13 and 0.24, respectively], ADOS CSS-SA [semi-partial correlations = 0.03 and 0.15, respectively], or ADOS CSS [semi-partial correlations = 0.11 and 0.21, respectively] at Time 3.

Sensory Seeking.—SPA Sensory Seeking behaviors at Time 1 and changes from Time 1 to Time 2 were not significantly related to ADOS CSS-RRB [semi-partial correlations = 0.00 and 0.10, respectively], ADOS CSS-SA [semi-partial correlations = 0.05 and 0.26, respectively], or ADOS CSS [semi-partial correlations = -0.01 and 0.18, respectively] at Time 3. Despite the nonsignificant results for semi-partial correlations, it is apparent in Figure 1 that the unadjusted value for change in sensory seeking scores from Time 1 to Time 2 significantly predicted ADOS CSS-SA, and the confidence interval for the adjust value just barely crossed the 0 line, with closely aligned effect sizes for the adjusted and unadjusted values. See Figure 1.

See Supplementary Material for descriptive information about treatment groups, returners/nonreturners, and full model results with covariates.

Replication Analyses: SEQ.

Hyporeactivity.—SEQ Hyporeactivity at Time 1 and changes from Time 1 to Time 2 were not significantly related to ADOS CSS-RRB [semi-partial correlations = 0.12 and 0.00, respectively], ADOS CSS-SA [semi-partial correlations = 0.23 and 0.20, respectively], or ADOS CSS [semi-partial correlations = 0.18 and 0.14, respectively] at Time 3.

Hyperreactivity.—At Time 1, SEQ Hyperreactivity was significantly associated with ADOS CSS-RRB at Time 3 [95% CI (0.26, 3.55); semi-partial correlation = 0.31]. Increases in SEQ Hyperreactivity from Time 1 to Time 2 were not significantly associated with higher ADOS CSS-RRB [95% CI (−1.33, 2.88); semi-partial correlation = 0.10], ADOS CSS-SA [95% CI (−1.98, 1.93); semi-partial correlation = 0.00] or ADOS CSS [95% CI (−1.54, 2.28); semi-partial correlation = 0.05]. See Figure 2.

Sensory Seeking.—SEQ Sensory Seeking behaviors at Time 1 and changes from Time 1 to Time 2 were not significantly related to ADOS CSS-RRB [semi-partial correlations = 0.05 and 0.16, respectively], ADOS CSS-SA [semi-partial correlations = 0.07 and 0.10, respectively], or ADOS CSS [semi-partial correlations = 0.02 and 0.11, respectively] at Time 3.

Discussion

Research indicates that most children with ASD display atypical sensory reactivity patterns (Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson et al., 2009; Leekam, Nieto, Libby, Wing, & Gould, 2007) and these patterns may be present in infants at elevated likelihood for developing ASD prior to receiving a diagnosis (Sacrey et al., 2015; Turner-Brown et al., 2013; Wolff et al., 2019). Expanding this work, these results link early sensory reactivity patterns at 14 and 23 months with severity of ASD symptoms during the preschool years. Observations of child hyporeactivity at 14 months may be particularly helpful in predicting later ASD severity during the preschool years. The results of these analyses indicated that higher hyporeactivity to sensory stimuli at 14 months may be an indicator of more severe overall ASD symptoms and social-communication symptoms between 3 and 5 years old. In addition, increases in observed hyporeactivity, and potentially seeking, from 14 to 23 months may be indicators of more severe ASD social communication symptoms and restricted, repetitive behaviors between 3 and 5 years old. Replication results using parent report of sensory reactivity indicated that hyperreactivity at 14 months may be an indicator of more severe restricted, repetitive behaviors between 3 and 5 years old.

These results suggest that hyporeactivity and hyperreactivity at 14 months as well as increases in hyporeactivity and seeking from 14 to 23 months may provide new areas of exploration into the understanding of the emergence of ASD symptoms during the period prior to the formal diagnosis. Identification of these early sensory precursors may facilitate early treatment that aims to ameliorate the later severity of ASD, though more research is needed to identify specific treatments that may be advantageous (Baranek et al., 2015; Barton, Reichow, Schnitz, Smith, & Sherlock, 2015). Given the possible cascading effects of early atypical sensory reactivity on the development of social skills (Baranek et al., 2018), treatments that target these sensory reactivity patterns may be particularly beneficial. Since

atypicalities in early sensory reactivity have been associated with lower language skills (Philpott-Robinson, Lane, & Harpster, 2016; Watson et al., 2011), mood and anxiety symptoms (Ben-Sasson et al., 2008; Green, Ben-Sasson, Soto, & Carter), lower adaptive behavior (Ausderau et al., 2016; Rogers, Hepburn, & Wehner, 2003; Williams et al., 2018), and increased parental stress (Ausderau et al., 2016; Kirby, White, & Baranek, 2015; Ben-Sasson, Soto, Martinez-Pedraza, & Carter, 2013), ameliorating the impact of these symptoms as soon as possible has many potential benefits for the child and their family. In addition, there is emerging evidence that parents of a child at elevated risk for developing ASD may respond differently to their child when the child displays hyporeactive sensory patterns (Kinard et al., 2017). Since many early interventions for children with ASD utilize a parent-mediated model (Bradshaw, Koegel, & Koegel, 2017; Harrop, Gulsrud, Shih, Hovsepyan, & Kasari, 2017; Pickles et al., 2016; Watson et al., 2017), future research will help to understand the impact of sensory reactivity patterns on parent behavior and identify treatments that assist the parent in utilizing optimal strategies for responsive parenting when an infant is less responsive to sensory stimuli than would be expected.

The differing results from direct observation versus parent report indicates that these two modalities of gathering information about sensory reactivity patterns are complementary. Of particular interest, parent-reported hyperreactivity at 14 months significantly predicted the severity of RRB symptoms in the children at preschool age with a semi-partial correlation of 0.31, whereas observed hyperreactivity at 14 months was nonsignificant, with a semi-partial correlation of only 0.12. Thus, each assessment method provides novel predictive information about later ASD severity. It is possible that, unlike trained clinicians, parents have more difficulty identifying certain aspects of sensory reactivity (e.g., hyporeactivity). For example, hyporeactivity (a lack of or lessened response to sensory stimuli) may be more difficult for parents to recognize than hyperreactivity (an increased response to sensory stimuli). While parent report is often preferable for researchers (cheaper, less time consuming), it is important that future research in this area acknowledge that each method of gathering information about sensory patterns may yield novel information. Of note, multiple results found with the parent-report measure (SEQ) and the observational measure (SPA) are in the same direction, although not completely aligned in terms of significance or magnitude of effects (see Figures 1 and 2).

While atypical sensory reactivity patterns have been reported in infants at risk for ASD as young as 6 months (Sacrey et al., 2015), the relationship between these very early patterns, as well as changes in these patterns during the second year of life, and later ASD severity remains unknown. Future research would benefit from extending this work to children younger than 14 months who are at risk for neurodevelopmental disorders such as ASD. These early sensory reactivity patterns may also provide useful information to define empirically-supported subtypes of ASD (Ausderau et al., 2015; 2016; Lane et al., 2010). A more detailed exploration of ASD symptom profiles may assist with this line of inquiry. Identifying subtypes may be useful in treatment planning and implementation.

Previous research has indicated that hyperreactivity and sensory seeking behaviors between 20 and 24 months may be related to later ASD diagnoses (Baranek et al., 2018; Ben-Sasson et al., 2008; 2013; Green, Ben-Sasson, Soto, & Carter, 2012; Wolff et al., 2019). The results

of our work suggested that hyperreactivity reported by parents at 14 months is associated with more severe restricted, repetitive behaviors between 3 and 5 years old. Although sensory seeking behavior prior to two years was not significantly related to ASD symptom severity during the preschool years, the effect size for the change in observed sensory seeking behaviors from 14 to 23 months approached the same order of magnitude found for change in observed hyporeactivity across these two time points, with a confidence interval that barely crossed 0. Comparing our findings related to change in sensory seeking behaviors in at-risk children during the second year of life to cross-sectional studies which have reported significant associations between ASD symptoms and sensory seeking behaviors (Boyd et al., 2010; Watson et al., 2011) in older children diagnosed with ASD suggests that sensory seeking behaviors may be continuing to increase across the toddler period in children who are on a trajectory to exhibit more severe social-communication symptoms of ASD as preschoolers. Indeed, Baranek et al. (2018) noted sensory seeking behaviors around 24 months of age may be more strongly related to later ASD diagnoses and symptoms rather than symptoms at 14 months or changes between 14 and 23 months, as our analyses examined. Changes in SPA hyperreactivity scores from 14 to 23 months also showed a notable association with the severity of ASD symptoms at preschool age (especially RRB symptoms), albeit nonsignificant (see Figure 1). Further examinations of hyperreactivity and sensory seeking behaviors using direct observation and their relationship with later ASD diagnosis and symptomology are needed. It is also possible that hyporeactivity, unlike hyperreactivity and sensory seeking, aligns more with specific early ASD symptoms such as decreased response to name and fewer responses to social bids.

The results of this work should be considered in light of several limitations. First, the large attrition from Time 2 to Time 3 and missing outcome data limits the interpretation of these results and additionally impacts the statistical power for detecting significant associations, despite the use of multiple imputation. In addition to this potential limitation in power for the analyses completed, the sample size available for this study limited our ability to conduct more advanced analyses. In particular, analyses utilizing diagnostic outcomes was statistically difficult (due to missing data) and therefore beyond the scope of this work. In addition, of the children who returned for Time 3 visits, the age range was large, though this was controlled for in analyses (with no significant impact of this variable). This sample was composed of predominantly White and highly-educated families; despite being representative of the local community, it is possible that these results may not be consistent in more diverse populations. In addition, children who did not return for Time 3 visits were more likely to be Black and to have lower education levels. It is possible that these and other possible (unmeasured) differences between those who returned at Time 3 and those who did not impacted the results of this work in an unknown manner. Overall, future work would benefit from larger samples, complete datasets across timepoints, and more consistent timing of outcome data acquisition. The results of this work focused on direct observation of sensory reactivity as a strategy to reduce potential biases due to parents being aware of the study group to which they were assigned in this intervention trial; however, the lack of a treatment group by SPA/SEQ interaction effect suggests that parent reports on the SEQ were not biased as a result of their knowledge of treatment group assignment. Given the greater feasibility of using parent report measures rather than observational measures in both

research and clinical settings, further investigation of whether other parent report measures will yield findings related to hyporeactivity and sensory seeking patterns that better align with the observational findings for these two patterns in the current study. It is important to note that this work did not examine diagnostic outcomes during the preschool period. Using a dimensional approach, these analyses examined the ASD symptom severity across children who did and did not receive a diagnosis of ASD between 3 and 5 years old. This approach, while limiting in some ways, acknowledges that many children with neurodevelopmental disorders and developmental delays display ASD-related symptoms, even if they do not meet full diagnostic criteria for ASD. This likely is particularly true for this sample, as represented by the distribution of CSS scores (see Figures 1 and 2), given their initial identification with a parent report tool designed to assess early symptoms predictive of later ASD. In addition, since elevated cut-offs on the FYI, including the Sensory-Regulatory Functions domain, were required for inclusion in the study, this sample may have more atypical sensory reactivity patterns than other community samples, though less than samples of children diagnosed with ASD. Although treatment group was included as a covariate in this study (without statistically significant intervention effects), future treatment studies with larger samples should assess whether treatment affects sensory reactivity and its relationship with later ASD severity.

Overall, these results indicate that early sensory reactivity patterns, particularly observed hyporeactivity and parent-reported hyperreactivity, may be useful in predicting the severity of later ASD symptoms. In addition, these sensory patterns provide important targets for early interventions for at-risk children under 24 months that may attenuate the later increased ASD severity. Future research should continue to explore evidence-based practices that can improve atypical sensory reactivity and the potential downstream social deficits. In addition, researchers may find that early sensory reactivity patterns are predictive of empirically-defined subtypes within ASD that have different functional and adaptive outcomes and require specific, tailored treatments (Ausderau et al., 2016).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
SPA Results

Note: Panel A = 95% Confidence Intervals for Regression Results for Analysis of Association. Panel B = Scatterplot of ADOS Scores at Time 3 and Difference in SPA Hypo between Time 1 and Time 2. Panel C = Scatterplot of ADOS Scores at Time 3 and Difference in SPA Hyper between Time 1 and Time 2. Panel D = Scatterplot of ADOS Scores at Time 3 and Difference in SPA Seeking between Time 1 and Time 2. Blue Line represents unadjusted model; Red Line represents adjusted models. Adjusted models include covariates [age at Time 3, Treatment Group, Mullen Visual Reception Score at Time 1, SPA Domain scores at Time 1 (for difference analyses only)]. n.s. = Not Statistically Significant; * = Statistically Significant

Figure 2.**SEQ Results**

Note: Panel A = 95% Confidence Intervals for Regression Results for Analysis of Association. Panel B = Scatterplot of ADOS Scores at Time 3 and Difference in SEQ Hypo between Time 1 and Time 2. Panel C = Scatterplot of ADOS Scores at Time 3 and Difference in SEQ Hyper between Time 1 and Time 2. Panel D = Scatterplot of ADOS Scores at Time 3 and Difference in SEQ Seeking between Time 1 and Time 2. Blue Line represents unadjusted model; Red Line represents adjusted models. Adjusted models include covariates [age at Time 3, Treatment Group, Mullen Visual Reception Score at Time 1, SPA Domain scores at Time 1 (for difference analyses only)]. n.s. = Not Statistically Significant; * = Statistically Significant

Table 1.

Background Information (n=87).

	Mean (SD)	Mean (SD)	Mean (SD)
	Time 1 ^a	Time 2 ^b	Time 3 ^c
Age	14 (0.77)	23 (0.86)	54 (11.31)
MSEL (T-Scores)			
Fine Motor	47.75 (9.82)	41.20 (12.56)	-
Visual Reception	44.80 (10.80)	46.23 (13.08)	-
Receptive Language	32.76 (10.88)	44.41 (16.44)	-
Expressive Language	35.08 (11.48)	41.27 (12.59)	-
	n (%)		
Sex (males)	60 (69)		
Child Race ^d			
White	60 (70)		
African-American	17 (20)		
Mixed race/Other	9 (10)		
Primary Caregiver's Education Level			
Less than High School	3 (3)		
High School Diploma/GED	11 (13)		
Vocational/Associates Degree/Some College	15 (17)		
4-year College Degree	24 (28)		
Graduate/Professional Degree	34 (39)		

Note: MSEL= Mullen Scales of Early Learning;

^a n=87;^b n=83;^c n=45;^d 1 parent did not report child's race.