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Toddlers at Elevated Likelihood for Autism: Exploring Sensory and Language Treatment Predictors

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Abstract

Baseline child characteristics may predict treatment outcomes in children with or at elevated likelihood of developing autism (EL-ASD). Little is known about the role of child sensory and language features on treatment outcome. Participants were randomly assigned to a parent-mediated intervention or control condition. Analyses explored the relationship between baseline child sensory and language characteristics and changes in ASD symptoms over approximately 9 months. Higher baseline sensory hyporeactivity was significantly related to less improvement in social communication (SC) for the treatment group only. More baseline atypical vocalizations were significantly related to less improvement on SC across treatment and control groups. This work provides an initial framework to encourage the tailoring of interventions for EL-ASD children, suggesting sensory reactivity and atypical vocalizations may be useful behaviors to consider in treatment planning.

Keywords

autism spectrum disorders, disabilities and development delays, language and communication, child development, infants and toddlers, young children

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Background

Autism spectrum disorder (referred to throughout as autism) is a neurodevelopmental difference that is characterized by delays or differences in developing social communication (SC) skills and the presence of restricted and repetitive behaviors (RRBs). Symptoms of autism usually consolidate into a diagnosis when a child is between 2 and 3 years of age; however, the median age of diagnosis is older than 4 years in the United States (Shaw et al., 2020). Significant research efforts have identified early screening and symptom presentations that may precede a formal diagnosis.

As research in early identification improves accuracy of a later diagnosis, recent studies have run parallel to explore child characteristics that may predict later child outcomes. This is in an effort to better understand child trajectories and improve tailored treatments for children with, or at elevated likelihood for neurodevelopmental difference such as autism (EL-ASD; Bearss et al., 2015; Garrido et al., 2017; Pellecchia et al., 2016; Schreibman et al., 2009; Siller et al., 2013; Tamis-Lemonda et al., 2001; Warren et al., 2010). EL-ASD children, identified due to having a sibling with autism or through early screening, can begin early intervention (EI) services by 18 months of age (or earlier), if sufficient symptomology of autism or other developmental delay can be identified. EI studies have focused on the efficacy of applied behavior analysis (ABA)-based treatment strategies, including naturalistic developmental behavioral interventions (NDBI; Landa, 2018). These studies have found modest effects on improving functional outcomes of EL-ASD children (Vivanti et al., 2018). NDBIs are correlated with increased adaptive behavior and intelligence quotient (IQ) in children with autism (Vivanti & Rogers, 2014). EI-related improvements have been related to treatment intensity in some studies, with treatments of more than 30 hours a week associated with maximal gains (Eldevik et al., 2009), although this needs further exploration (Crank et al., 2021). Research has suggested that NDBIs involving caregiver and clinician components may be most effective (Hampton & Kaiser, 2016), although the relationship between provider (caregiver vs. clinician) and treatment outcome is unclear (Crank et al., 2021; Rogers et al., 2020). High-intensity interventions for young children with autism (up to 40 hr per week) and high caregiver and clinician involvement are both expensive and time-consuming (Leigh & Du, 2015; Ouyang et al., 2014; Pellicano et al., 2014). This can lead to substantial family and parental stress (Estes et al., 2019), as well as financial burden. Given the cost and burden of these interventions, identifying mechanisms of improvement or factors that contribute to better functional outcomes for children is a top priority to tailor EIs.

Certain child characteristics, such as high interest in toy contact, were related to better language outcomes in response to treatment (Schreibman et al., 2009; Yoder & Stone, 2006). Research has also suggested that higher baseline cognitive ability is a predictor of more improvement over the course of intervention (Grzadzinski et al., under review; Harris & Handleman, 2000), though more studies are needed, as others have found that a lower baseline IQ is correlated with greater increases in cognitive scores (Ben-Itzchak et al., 2014) and some found no IQ effects (Sutera et al., 2007). In addition, nuanced exploration of child characteristics may reveal new information regarding mechanisms of treatment outcome, which could ultimately be incorporated into early intervention practices.

Though understudied, research has suggested that 70% to 90% of children diagnosed with autism display high levels of sensory features, and the *Diagnostic and Statistical Manual of Mental Disorders*, 5th Edition (*DSM*-5) now recognizes some sensory features under RRBs (Baranek et al., 2006; Ben-Sasson et al. 2009; López & Leekam, 2007). Sensory features are noted across modalities (e.g., auditory, tactile) and are often characterized into three different sensory response categories that regularly coexist. Sensory hyporeactivity is defined as either a decreased or absent reaction to sensory stimuli, hyperreactivity is an aversive or avoidant reaction to sensory stimuli, and sensory seeking behaviors extend, intensify, or modulate sensory experiences (Baranek et al., 2006; Ben-Sasson et al., 2008, 2009). Hyporeactivity has consistently been reported in young children with autism as well as in EL-ASD children (Baranek et al., 2006, 2013; Ben-Sasson et al. 2009). Hyperreactivity and sensory seeking behaviors are also documented (Baranek et al. 2019; Ben-Sasson et al., 2008, 2013; Brock et al., 2012; Wolff et al., 2019). Atypical sensory reactivity has been found in EL-ASD infants and toddlers in several studies, suggesting it as a potential precursor to an autism diagnosis. One infant sibling study found that at 12 months, children later diagnosed with autism showed elevated hyperreactivity on a parent report measure compared with children that did not go on to develop autism (Wolff et al., 2019). In another study, parents reported sensory differences among infant siblings, some as young as 6 months of age, in children who later met criteria for an autism diagnosis (Sacrey et al., 2015). Similarly, sensory reactivity reported by parents at 12 months was found to be a predictor of a later autism diagnosis in a community sample (Turner-Brown et al., 2013). Research has shown that the patterns of sensory reactivity also matter in child development of other skills. For instance, children with hyporeactivity presented with more communication deficits, including delays in spoken language (Baranek et al., 2013; Flippin & Watson, 2011; Patten et al., 2013; Philpott-Robinson et al., 2016). Although there is growing research that supports the relationship between early sensory reactivity and later autism diagnosis (Bizzell et al., 2020; Grzadzinski et al., 2020; Sacrey et al., 2014; Wolff et al., 2019), research has not explored if sensory reactivity patterns impact treatment outcomes.

EL-ASD toddlers who go on to be diagnosed with autism also show unique patterns of communication and language skills compared with typically developing peers. For example, between 18 and 24 months of age, children who go on to receive a diagnosis of autism have been found to have a lower proportion of speech-like vocalizations (Plumb & Wetherby, 2013). EL-ASD infants, identified due to ASD diagnosis in an older sibling, produce fewer total speech-like vocalizations at 6, 9, and 12 months (Paul et al., 2011), while typically developing infants were 17 times more likely to use canonical babbling (vocalizations that include at least one well-formed syllable, with each having at least one full vowel-like element and at least one consonant-like element with rapid transition between the two) at 9 to 12 months and 6 times more likely at 15 to 18 months (Patten et al., 2014). Parents of children with autism have indicated that their child's use of speech-like vocalizations is significantly different from reports of parents of typically developing children at 12 months of age, but did not consistently differ from those with other developmental disabilities (Watson et al., 2007). Global language skills, such as Verbal IQ, have been found to be a predictor of treatment outcomes (Grzadzinski et al., under review), but specific vocalization components, such as directedness of speech, frequency of canonical babbling, or atypical vocalizations, may be related to treatment outcomes as well. Further exploration of the impact of vocalization patterns on treatment outcomes in children at an elevated likelihood for or diagnosed with autism could provide new targets for treatment and tailor interventions.

Although the impacts of early sensory reactivity and vocalization patterns on a later autism diagnosis have been studied, their impact on outcomes is unknown. Thus, the aim of this study is to examine whether sensory reactivity and vocalization patterns impact changes in SC and RRB. We hypothesize that aspects of sensory reactivity (hyporeactivity) and vocalization patterns will predict SC and RRB behaviors about 9 months later, regardless of treatment status. By using multiple measures of sensory reactivity (parent report and direct observation), nuanced examinations of vocalization patterns, and a new treatment outcome measure (the Brief Observation of Social Communication Change; BOSCC; Grzadzinski et al., 2016), the results of this study will maximize the potential of data collected through a completed randomized control trial (Watson et al., 2017) to provide the field with novel intervention targets for EL-ASD toddlers.

Table 1. Demographics (n = 87).

Demographic Variables	REIM (42) Timepoint 1 mean (SD)	REIM (42) Timepoint 2 mean (SD)	ART (45) Timepoint 1 mean (SD)	ART (45) Timepoint 2 mean (SD)
Age (in months)	14 (0.78)	22 (0.79)	14 (0.77)	23 (0.99)
Mullen Scales of Early Learning Domains				
Fine motor	48 (9.21)	43 (11.09)	47 (10.44)	40 (13.67)
Visual reception	47 (11.17)	47 (12.30)	43 (10.04)	45 (13.80)
Receptive language	33 (12.33)	47 (15.76)	33 (9.47)	42 (16.95)
Expressive language,	36 (12.08)	41 (13.53)	34 (10.98)	41 (11.86)
n (%)				
Sex (males)	32 (76)		28 (62)	
Child race				
White	31 (74)		29 (64)	
African-American	6 (14)		12 (27)	
Mixed race/other	5 (12)		4 (9)	
Primary caregiver education level				
Less than high school	0 (0)		3 (7)	
High-school diploma/High-school equivalency diploma	7 (16.7)		4 (9)	
Vocational/associates/some college	8 (19)		7 (16)	
4-year college degree	11 (26)		13 (29)	
Graduate/professional degree	16 (38)		18 (40)	

Note. REIM = Referral to Early Intervention and Monitoring; ART = Adapted Responsive Teaching.

Method

Participants

This study included a sample of 87 EL-ASD toddlers (60 boys) identified at 12 months (±2 weeks) based on community screenings with the *First Year Inventory version 2.0* (FYI; Baranek et al., 2003). Participants were recruited by mailing the FYI to parents of children in the study catchment area, based on state birth records, just prior to the child's first birthday. The children were randomized to a parent-mediated early intervention (Watson et al., 2017; Adapted Responsive Teaching; ART; n = 45) or Referral to Early Intervention and Monitoring (REIM; n = 42); referred to as Group in analyses. Participants were seen at baseline (prior to treatment onset) and ~9 months later, post-treatment. Time 1 (14 months, ±0.77 months) and Time 2 (23 months, ±0.86), respectively. Additional eligibility criteria included birthweight >2,500 g and English spoken as a primary language at home. All participants' parents provided their written consent before evaluation began, as in accordance with protocols approved by the Institutional Review Board (see Table 1).

Measures

Cognitive Abilities

Mullen Scales of Early Learning (MSEL). At Time 1 and Time 2, children were administered the MSEL (see Table 1; Mullen, 1995). The MSEL yields standard *T*-scores in the domains of fine motor, visual reception (VR), receptive language, and expressive language (EL) at Time 1.

VR and EL, as proxies of nonverbal and verbal developmental level, respectively, were covariates in analyses.

Sensory Reactivity

Sensory Processing Assessment (SPA). This behavioral measure assesses a child's sensory reactivity to a variety of stimuli in a 15-minute play-based observation designed for children aged 6 months to 9 years of age (Baranek, 1999; Baranek et al., 2007, 2013). Results yield scores in hyporeactivity (a decreased orienting response to visual, tactile, and auditory stimuli; SPA-Hypo), hyperactivity (an aversive or avoidant response to visual, tactile, and auditory stimuli; SPA-Hyper), and sensory seeking behaviors (an intense craving, repetition or fascination of sensory experiences with objects or body; SPA-Seek). The SPA was administered at Time 1 (14 months, ±0.77 months), and administrators were blind to group status. Of the 87 children, three were lost to follow-up at Time 2, and for one additional child, only parent report assessments were available at Time 2.

Sensory Experiences Questionnaire (SEQ). This questionnaire consists of 43 items appropriate for children 5 months to 12 years of age, and assesses the type and frequency of a child's sensory reactions to everyday stimuli (Baranek, 1999; Baranek et al., 2006, 2013; Little et al., 2011). Responses are rated on a 5-point Likert-type scale ranging from 1 (*almost never*) to 5 (*almost always*); higher scores indicate more sensory symptoms. The SEQ, a companion to the SPA, yields scores on hyporeactivity, hyperreactivity, and sensory seeking behaviors and has high test–retest reliability (Little et al., 2011) and internal consistency (Baranek et al., 2006). At Time 1, parents completed the SEQ about their child.

Vocalizations

At Time 1, child vocalizations were coded as described in Garrido et al. (2017). Vocalizations were coded from 30 min of video observation of the child in naturalistic and semi-naturalistic social/play contexts. The context of the first 10 min was a parent–child free-play with a standard set of developmentally appropriate toys. Video recordings of the administration of the Communication and Symbolic Behavior Scales Developmental Profile (CSBS-DP; Wetherby & Prizant, 2002) were used to code child vocalizations for an additional 20 min. With vocalization data missing for one child at Time 1, a minimum of 75 children were available for all analyses.

As described in Garrido et al. (2017), two types of speech vocalizations (canonical and non-canonical) and three types of nonspeech vocalizations (atypical, distress, and pleasure) were coded; see Figure 1. Vocalizations were coded as discrete events with an onset occurring when the child initiated a sound and an ending if there was at least 1 second break in the child's vocalization. All vocalizations were coded as either directed to a communication partner or non-directed (see Garrido et al., 2017 for coding criteria). Frequencies of each vocalization were summed. Three coders who were unaware of child information were trained on non-study videos to identify the types of vocalizations described in Figure 1 and attained at least 90% event-by-event agreement with the established training video codes before coding study videos. To assess interrater reliability, 20% of the study videos were randomly selected to be independently coded by two coders, both of whom were unaware of which videos would be double-coded. Given the time-consuming and therefore costly process required for coding, double coding 20% of the study was deemed feasible within the resources available for the study as well as sufficient to evaluate reliability of the coded data. Reliability was estimated from intraclass correlation coefficients (ICCs), using SPSS statistics version 22.0, using a two-way random effects model for absolute agreement. Interrater agreement was excellent across vocalization type, with intraclass correlation coefficients ranging from 0.91 to 0.995 (see Garrido et al. (2017) for additional

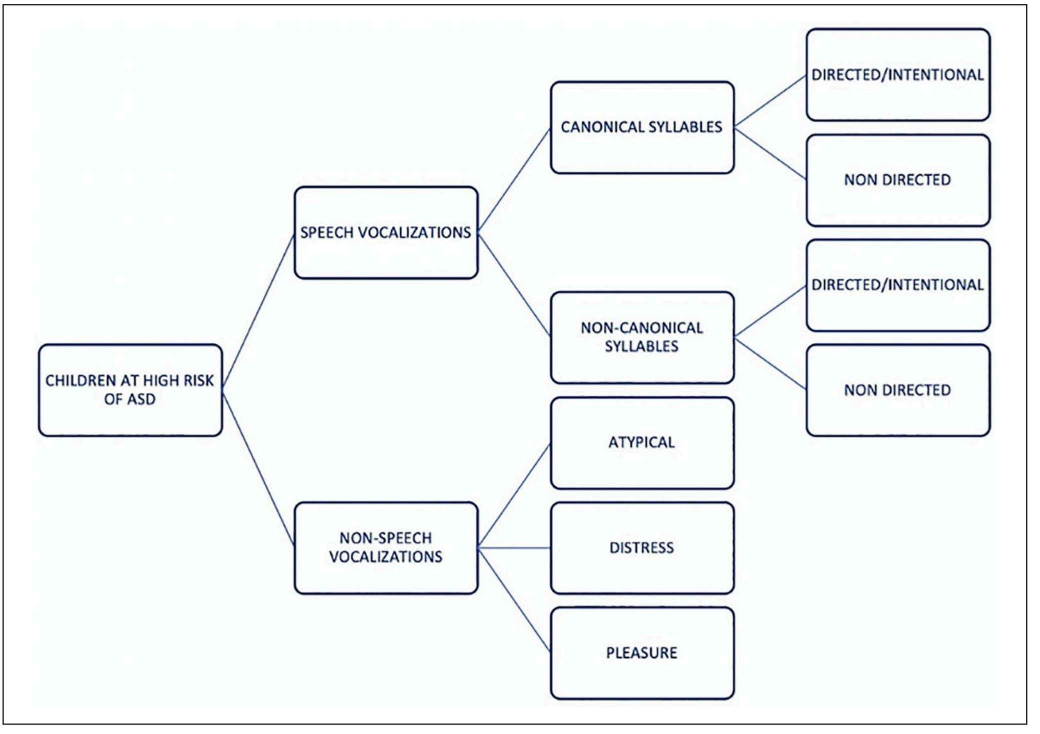

Figure 1. Language variables.

details). One participant was missing language coding, and was therefore removed from analyses.

Autism Symptoms

The BOSCC (Grzadzinski et al., 2016) is a treatment response measure that quantifies changes in autism symptoms. The BOSCC coding scheme was applied to parent–child free-play videos at Time 1 (14 months, ±0.77) and Time 2 (23 months, ±0.86) to specifically examine changes in child autism behaviors in the SC (BOSCC-SC) and RRB (BOSCC-RRB) domains. The 10-min parent–child free-play video was the same as was coded for the child vocalizations described above (though the addition of the first 20 min of the CSBS was specific to vocalization coding). Prior to coding independently, coders participated in training that involved review of the BOSCC coding scheme, practice watching and coding video observations, and participation in discussions with already reliable coders. New coders obtained interrater agreement standards that the authors deemed adequate: no more than three items with more than one point disagreement AND within four points across summed totals for all items, across three consecutive videos (Grzadzinski et al., 2016). Codes from coders that had not met the above interrater agreement standards were never included in data sets. Regular consensus meetings were held to confirm ongoing reliability on the BOSCC across coders. During the coding process, to maintain reliability standards, a primary coder was randomly chosen and used for data analysis, while a secondary coder was randomly chosen and used for reliability analysis. This method was chosen, rather than a fully crossed model, due to the time-consuming nature of coding and the availability of coders (Grzadzinski et al., 2016). Coders were blind to group and timepoint.

Table 2. Correlations.

Variables of Interest		BOSCC RRB ratio change	BOSCC SC ratio change	Canonical Directed	Canonical Non-Directed	Non-Canonical Directed	Non-Canonical Non-Directed	Atypical vocalizations	Distress vocalizations	Pleasure vocalizations	SPA hyporeactivity	SPA hyperreactivity	SPA seeking	SEQ hyporeactivity	SEQ hyperreactivity	SEQ seeking
BOSCC RRB ratio change	Pearson's correlation	1														
	Sig. (2-tailed)															
	N	75														
BOSCC SC ratio change	Pearson's correlation	−.286*	1													
	Sig. (2-tailed)	0.013														
	N	75	83													
Canonical Directed	Pearson's correlation	0.157	−0.051	1												
	Sig. (2-tailed)	0.181	0.65													
	N	74	82	82												
Canonical Non-Directed	Pearson's correlation	−0.021	0.2	.283*	1											
	Sig. (2-tailed)	0.859	0.072	0.01												
	N	74	82	82	82											
Non-Canonical Directed	Pearson's correlation	0.16	−0.06	.320**	0.181	1										
	Sig. (2-tailed)	0.174	0.59	0.003	0.103											
	N	74	82	82	82	82										
Non-Canonical Non-Directed	Pearson's correlation	0.09	0.105	0.018	.665**	.273*	1									
	Sig. (2-tailed)	0.447	0.346	0.87	0	0.013										
	N	74	82	82	82	82	82									
Atypical vocalizations	Pearson's correlation	−.239*	.363**	−0.049	0.139	0.211	0.178	1								
	Sig. (2-tailed)	0.04	0.001	0.664	0.213	0.057	0.109									
	N	74	82	82	82	82	82	82								
Distress vocalizations	Pearson's correlation	−0.094	−0.013	0.103	−0.022	0.098	0.114	0.024	1							
	Sig. (2-tailed)	0.426	0.907	0.359	0.843	0.379	0.308	0.831								
	N	74	82	82	82	82	82	82	82							
Pleasure vocalizations	Pearson's correlation	0.154	−0.006	0.102	0.105	−0.022	−0.036	0.196	−0.115	1						
	Sig. (2-tailed)	0.189	0.959	0.362	0.348	0.842	0.747	0.078	0.305							
	N	74	82	82	82	82	82	82	82	82						
SPA hyporeactivity	Pearson's correlation	−0.041	.272*	−0.19	0.036	−.273*	0.025	0.097	0.019	−0.004	1					
	Sig. (2-tailed)	0.726	0.013	0.088	0.745	0.013	0.822	0.384	0.865	0.974						
	N	75	83	82	82	82	82	82	82	82	99					
SPA hyperreactivity	Pearson's correlation	−0.031	.234*	0.02	−0.083	0.013	0.033	0.042	.237*	−0.146	0.029	1				
	Sig. (2-tailed)	0.79	0.033	0.857	0.457	0.907	0.765	0.71	0.032	0.191	0.774					
	N	75	83	82	82	82	82	82	82	82	99	99				
SPA seeking	Pearson's correlation	0.114	−0.148	−0.084	−0.02	−0.052	0.122	−0.127	−0.049	−0.188	0.104	0.136	1			
	Sig. (2-tailed)	0.329	0.181	0.453	0.86	0.64	0.275	0.257	0.662	0.091	0.305	0.18				
	N	75	83	82	82	82	82	82	82	82	99	99	99			
SEQ hyporeactivity	Pearson's correlation	−0.153	0.175	−0.076	0.041	−.387**	−0.022	−0.09	0.076	−0.067	.311**	−0.024	0.088	1		
	Sig. (2-tailed)	0.191	0.113	0.499	0.712	0	0.847	0.423	0.497	0.551	0.002	0.813	0.387			
	N	75	83	82	82	82	82	82	82	82	99	99	99	100		
SEQ hypereactivity	Pearson's correlation	0.055	−0.014	0.202	0.034	−0.007	−0.026	−0.076	0.146	0.008	0.083	0.115	−0.181	.346**	1	
	Sig. (2-tailed)	0.638	0.898	0.068	0.763	0.949	0.816	0.497	0.19	0.942	0.414	0.258	0.074	0		
	N	75	83	82	82	82	82	82	82	82	99	99	99	100	100	
SEQ seeking	Pearson's correlation	0.009	0.028	−0.111	0.033	0.132	0.01	−0.049	−0.031	0.085	−0.028	0.133	−0.005	−0.084	0.113	1
	Sig. (2-tailed)	0.939	0.804	0.322	0.771	0.237	0.928	0.664	0.783	0.446	0.781	0.188	0.963	0.406	0.265	
	N	75	83	82	82	82	82	82	82	82	99	99	99	100	100	100

Note. BOSCC = Brief Observation of Social Communication Change; RRB = restricted and repetitive behaviors; SC = social communication; SPA = Sensory Processing Assessment; SEQ = Sensory Experiences Questionnaire.
*Correlation is significant at the .05 level (2-tailed). **Correlation is significant at the .01 level (2-tailed).

Twenty-seven videos, representing 15% of the coded samples, were randomly chosen for independent coding by two coders to assess inter-rater reliability (IRR). The coders were blind to which videos were being double-coded. The IRR for the SC and RRB domain was high (intra-class correlation coefficient = 0.85, 95% confidence interval [CI] = [0.69, 0.93] and 0.88, 95% CI = [0.75, 0.94]), respectively. Change scores in BOSCC-SC and BOSCC-RRB domains were calculated by obtaining ratio scores to take into account Time 1 values. The use of change scores was chosen due to the goals of the BOSCC as a metric used specifically for quantifying change over time. T1 BOSCC scores were used as a covariate in analyses.

Correlations. See Table 2 for correlation analyses.

Groups. Forty-five children were randomly assigned to the ART group, an adaptation of the Responsive Teaching Curriculum (Mahoney & Macdonald, 2007) built on the idea that pivotal behaviors play key roles in positive outcomes in infants both EL-ASD and with ASD. Forty-two children were randomly assigned to the REIM group, where the children and their families received no direct intervention services, but did receive contact from the project coordinator every 5 to 6 weeks. In the event that a parent indicated a need for help in accessing EI services, the project coordinator provided contact information and offered to initiate a referral (Watson et al., 2017).

Analyses. Multicollinearity tests revealed no multicollinearity between variables ($1 < \text{variance inflation factor [VIF]} < 10$). Moderation analyses (controlling for Time 1 MSEL-EL and MSEL-VR) were conducted with 10,000 bootstraps to assess whether the child characteristics (e.g., vocalization, sensory) significantly moderated the relationship between group (ART vs. REIM; binary dummy coded) and ratio changes in child SC (BOSCC-SC-ratio) and RRBs (BOSCC-RRB-ratio). In the absence of significant moderation effects, linear regressions were conducted to test main effects, without covariates (Model 1) and with covariates (Model 2; Time 1 verbal MSEL-EL and nonverbal MSEL-VR). An alpha level of .05 was used to determine significance. All analyses were conducted using IBM SPSS Statistics, and the moderation effect was tested using PROCESS v3.5 for SPSS (Hayes, 2017).

Results

Social Communication

See Table 3.

Sensory hyporeactivity. A moderation analysis revealed that there was a statistically significant interaction between SPA hyporeactivity and Group ($p = .02$) such that higher SPA Hyporeactivity at Time 1 was associated with fewer improvements in SC within the treatment group only. See Figure 2. Using the SEQ, moderation analyses testing the interaction between Group and Time 1 SEQ hyporeactivity were not statistically significant; subsequent main effect regression analyses also revealed that SEQ Hyporeactivity at Time 1 was not a significant predictor of BOSCC-SC-ratio.

Sensory hyperreactivity. A moderation analysis revealed that there was not a statistically significant interaction between SPA hyperreactivity and Group. Subsequent main effect regression models indicated that Time 1 SPA hyperreactivity was a significant predictor of BOSCC-SC-ratio—$\beta = 0.136$, $t = 2.17$, $p = .033$). However, when controlling for baseline VR and EL, SPA hyperreactivity fell just below the statistical threshold of significance—$\beta = 0.119$, $t(79) = 1.917$, $p = .06$.

Table 3. Moderation and main effects: BOSCC SC change ratio.

			Moderation Effects				Main Effects							
Variables			Coefficent	*SE*	*t*	Significance	Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
SPA (Observational)	Hyporeactivity	Hyporeactivity	0.02	0.04	0.42	0.67	___[a]	___				___		
		Group	-0.26	0.12	-2.23	**0.03**								
		Group X Hyporeactivity	0.12	0.05	2.45	**0.02**								
		Visual Reception	0.00	0.00	-1.54	0.13								
		Expressive Language	0.01	0.00	2.83	**0.01**								
	Hyperreactivity	Hyperreactivity	0.11	0.13	0.85	0.40	1	Hyperreactivity	0.14	2.17	**0.03**	0.23	0.05	___
		Group	-0.06	0.22	-0.28	0.78								
		Group X Hyperreactivity	0.02	0.15	0.15	0.88	2	Hyperreactivity	0.12	1.92	0.06	0.34	0.12	0.06
		Visual Reception	0.00	0.00	-2.05	**0.04**		Visual Reception	0.00	-1.96	0.05			
		Expressive Language	0.00	0.00	1.87	0.06		Expressive Language	0.00	1.89	0.06			
	Seeking	Seeking	-0.03	0.05	-0.73	0.47	1	Seeking	-0.04	-1.35	0.18	0.15	0.02	___
		Group	-0.02	0.16	-0.10	0.92								
		Group X Seeking	0.00	0.06	-0.03	0.97	2	Seeking	-0.03	-1.25	0.22	0.31	0.09	0.07
		Visual Reception	-0.01	0.00	-2.28	**0.03**		Visual Reception	0.00	-2.29	**0.02**			
		Expressive Language	0.00	0.00	1.52	0.13		Expressive Language	0.00	1.58	0.12			
SEQ (Parent Report)	Hyporeactivity	Hyporeactivity	0.03	0.06	0.53	0.60	1	Hyporeactivity	0.05	1.60	0.11	0.18	0.03	___
		Group	-0.12	0.15	-0.83	0.41								
		Group X Hyporeactivity	0.05	0.07	0.78	0.44	2	Hyporeactivity	0.06	1.92	0.06	0.34	0.12	0.09
		Visual Reception	0.00	0.00	-1.93	0.06		Visual Reception	0.00	-1.99	0.05			
		Expressive Language	0.00	0.00	2.47	0.02		Expressive Language	0.00	2.45	**0.02**			
	Hyperreactivity	Hyperreactivity	-0.05	0.07	-0.75	0.46	1	Hyperreactivity	-0.01	-0.13	0.90	0.01	0.00	___
		Group	-0.15	0.18	-0.85	0.40								
		Group X Hyperreactivity	0.07	0.09	0.79	0.43	2	Hyperreactivity	-0.01	-0.27	0.79	0.28	0.08	0.08
		Visual Reception	0.00	0.00	-1.97	0.05		Visual Reception	0.00	-2.12	**0.04**			
		Expressive Language	0.00	0.00	2.00	**0.05**		Expressive Language	0.00	2.04	**0.04**			
	Seeking	Seeking	0.02	0.07	0.26	0.79	1	Seeking	0.01	0.25	0.80	0.03	0.00	___
		Group	0.04	0.21	0.20	0.84								
		Group X Seeking	-0.02	0.08	-0.29	0.77	2	Seeking	0.00	0.01	0.99	0.28	0.08	0.08
		Visual Reception	0.00	0.00	-2.10	**0.04**		Visual Reception	0.00	-2.12	**0.04**			
		Expressive Language	0.00	0.00	1.93	0.06		Expressive Language	0.00	2.01	**0.05**			

(continued)

Table 3. (continued)

			Moderation Effects				Main Effects							
Variables			Coefficent	*SE*	*t*	Significance	Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
Canonical	Directed	Canonical Directed	0.00	0.00	-0.63	0.53	1	Canonical Directed	0.00	-0.46	0.65	0.05	0.00	_____
		Group	0.00	0.07	-0.03	0.97								
		Group x Canonical Directed	0.00	0.00	-0.14	0.89	2	Canonical Directed	0.00	-1.09	0.28	0.30	0.09	0.09
		Visual Reception	0.00	0.00	-2.20	**0.03**		Expressive Language	0.00	2.01	**0.05**			
		Expressive Language	0.00	0.00	1.99	0.05		Visual Reception	0.00	-2.23	**0.03**			
	Non-Directed	Canonical Non-directed	0.00	0.00	1.15	0.25	1	Canonical Non-directed	0.01	1.82	0.07	0.20	0.04	_____
		Group	-0.02	0.05	-0.36	0.72								
		Group x Canonical Non-directed	0.01	0.01	0.64	0.52	2	Canonical Non-directed	0.01	1.59	0.12	0.32	0.10	0.06
		Visual Reception	0.00	0.00	-2.05	**0.04**		Visual Reception	0.00	-2.26	**0.03**			
		Expressive Language	0.00	0.00	1.20	0.23		Expressive Language	0.00	1.22	0.23			
Non-Canonical	Directed	Non-canonical Directed	0.00	0.00	-0.91	0.37	1	Non-canonical Directed	0.00	-0.54	0.59	0.06	0.00	_____
		Group	-0.02	0.08	-0.23	0.82								
		Group x Non-Canonical Directed	0.00	0.00	0.16	0.88	2	Non-canonical Directed	0.00	-1.16	0.25	0.30	0.09	0.09
		Visual Reception	0.00	0.00	-2.30	**0.02**		Expressive Language	0.00	1.98	0.05			
		Expressive Language	0.00	0.00	1.96	0.05		Visual Reception	0.00	-2.37	**0.02**			
	Non-Directed	Non-canonical Non-directed	0.00	0.01	0.79	0.43	1	Non-canonical Non-directed	0.00	0.95	0.35	0.11	0.01	_____
		Group	0.00	0.06	-0.03	0.98								
		Group x Non-Canonical Non-Directed	0.00	0.01	-0.14	0.89	2	Non-canonical Non-directed	0.00	0.94	0.35	0.29	0.08	0.07
		Visual Reception	0.00	0.00	-2.22	**0.03**		Visual Reception	0.00	-2.26	**0.03**			
		Expressive Language	0.00	0.00	1.64	0.11		Expressive Language	0.00	1.66	0.10			

(continued)

Table 3. (continued)

Variables			Moderation Effects				Main Effects							
			Coefficent	*SE*	*t*	Significance	Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
Other Vocalizations	Atypical	Atypical	0.01	0.00	1.52	0.13	1	Atypical	0.01	3.49	**0.00**	0.36	0.13	______
		Group	-0.08	0.06	-1.25	0.22								
		Group x Atypical	0.00	0.00	0.83	0.41	2	Atypical	0.01	3.77	**0.00**	0.47	0.22	0.09
		Visual Reception	-0.01	0.00	-2.57	**0.01**		Visual Reception	0.00	-2.50	**0.01**			
		Expressive Language	0.00	0.00	2.28	**0.03**		Expressive Language	0.00	2.13	**0.04**			
	Distress	Distress	0.00	0.00	-0.88	0.38	1	Distress	0.00	-0.12	0.91	0.01	0.00	______
		Group	-0.07	0.07	-1.07	0.29								
		Group x Distress	0.00	0.00	1.18	0.24	2	Distress	0.00	-0.21	0.83	0.27	0.07	0.07
		Visual Reception	-0.01	0.00	-2.40	**0.02**		Visual Reception	0.00	-2.25	**0.03**			
		Expressive Language	0.00	0.00	1.81	0.08		Expressive Language	0.00	1.67	0.10			
	Pleasure	Pleasure	-0.01	0.01	-0.80	0.43	1	Pleasure	0.00	-0.05	0.96	0.01	0.00	______
		Group	-0.05	0.06	-0.84	0.40								
		Group x Pleasure	0.01	0.01	1.02	0.31	2	Pleasure	0.00	-0.17	0.86	0.27	0.07	0.07
		Visual Reception	0.00	0.00	-2.16	**0.03**		Visual Reception	0.00	-2.24	**0.03**			
		Expressive Language	0.00	0.00	1.74	**0.09**		Expressive Language	0.00	1.70	0.09			

Note. Models 1 and 2 represent effects before and while controlling for visual reception and expressive language. SPA = Sensory Processing Assessment; SEQ = Sensory Experiences Questionnaire. Bolded entries highlight significant results.
[a]SPA Hyporeactivity main effects were not run due to significant moderation effects, as described in the analyses section.

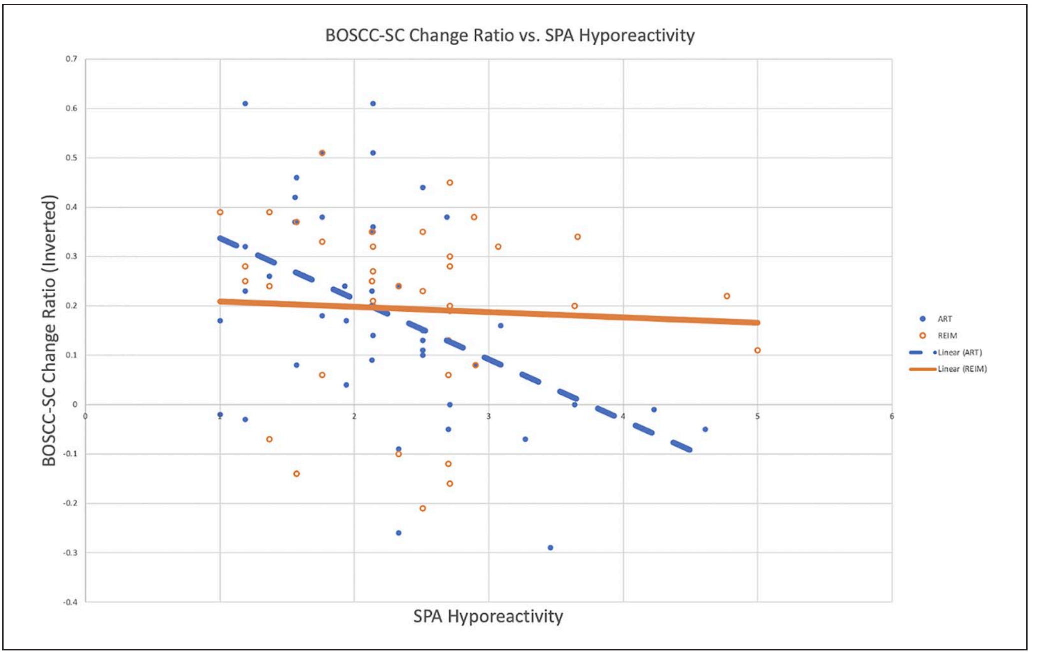

Figure 2. BOSCC SC change ratio versus SPA hyporeactivity.

Moderation analyses revealed that Time 1 SEQ hyperreactivity did not significantly moderate the relationship between Group and SC outcome; in addition, subsequent main effect regression models indicated that SEQ hyperreactivity at Time 1 was not a significant predictor of SC outcome.

Sensory seeking. Moderation analyses revealed that SPA and SEQ seeking at Time 1 were not significantly moderating the relationship between Group and SC outcome. Furthermore, main effect regression models indicated that Time 1 SPA Seeking and Time 1 SEQ Seeking were not significant predictors of BOSCC-SC-ratio.

Vocalizations. Moderation and subsequent main effect models analyses indicated that none of the vocalization variables, with the exception of atypical vocalizations, were significant moderators or main effect variables on BOSCC-SC-ratio. A moderation analysis revealed that there was not a statistically significant interaction between atypical vocalizations and treatment group (p = .408), suggesting that atypical vocalizations did not differentially impact BOSCC-SC-ratio based on treatment group. Main effect regression analyses indicated that atypical vocalizations significantly predicted BOSCC-SC-ratio, $\beta = 0.007$, $t(81) = 3.486$, $p = .001$, even when controlling for baseline VR and EL, $\beta = 0.008$, $t(81)= 3.769$, $p < .0001$; see Figure 3.

Restricted and Repetitive Behaviors

See Table 4.

Sensory hyporeactivity. Moderation analyses indicated that there was not a significant interaction between SPA hyporeactivity and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SPA hyporeactivity at Time 1 was not a significant predictor of BOSCC-RRB-ratio. Moderation analyses indicated that there was not a significant interaction

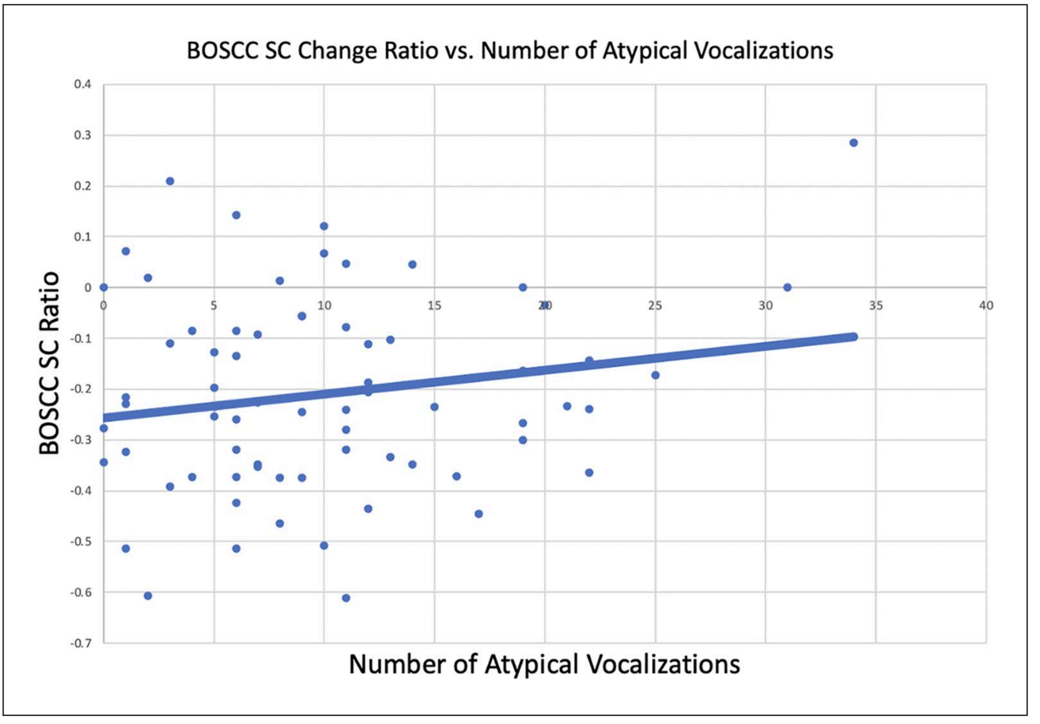

Figure 3. BOSCC SC change ratio versus number of atypical vocalizations.

between SEQ hyporeactivity and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SEQ hyporeactivity at Time 1 was not a significant predictor of BOSCC-RRB-ratio.

Sensory hyperreactivity. Moderation analyses indicated that there was not a significant interaction between SPA hyperreactivity and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SPA hyperreactivity at Time 1 was not a significant predictor of BOSCC-RRB-ratio. Moderation analyses indicated that there was not a significant interaction between SEQ hyperreactivity and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SEQ hyperreactivity at Time 1 was not a significant predictor of BOSCC-RRB-ratio.

Sensory seeking. Moderation analyses indicated that there was not a significant interaction between SPA seeking and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SPA seeking at Time 1 was not a significant predictor of BOSCC-RRB-ratio. Moderation analyses indicated that there was not a significant interaction between SEQ seeking and Group on BOSCC-RRB-ratio; subsequent main effect regression analyses revealed that SEQ seeking at Time 1 was not a significant predictor of BOSCC-RRB-ratio.

Vocalizations. Moderation and subsequent main effect models analyses indicated that none of the vocalization variables, with the exception of atypical vocalizations, were significant moderators or main effect variables on BOSCC-RRB-ratio. Moderation analyses indicated that atypical vocalization was not a significant moderator of the relationship between group and BOSCC-RRB-ratio. Subsequent main effect regression analyses indicated that Time 1 atypical

Table 4. Moderation and main effects: BOSCC RRB change ratio.

Variables			Moderation Effects: Coefficent	*SE*	*t*	Significance	Main Effects: Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
SPA (Observational)	Hyporeactivity	Hyporeactivity	0.06	0.06	1.04	0.30	1	Hyporeactivity	-0.01	-0.35	0.73	0.04	0.00	____
		Group	0.28	0.19	1.45	0.15								
		Group X Hyporeactivity	-0.10	0.08	-1.32	0.19	2	Hyporeactivity	0.00	0.09	0.93	0.16	0.03	0.03
		Visual Reception	0.00	0.00	0.97	0.33		Visual Reception	0.00	0.79	0.43			
		Expressive Language	0.00	0.00	0.91	0.37		Expressive Language	0.00	0.84	0.40			
	Hyperreactivity	Hyperreactivity	0.02	0.20	0.10	0.92	1	Hyperreactivity	-0.03	-0.27	0.79	0.03	0.00	____
		Group	0.13	0.34	0.39	0.69								
		Group X Hyperreactivity	-0.06	0.23	-0.28	0.78	2	Hyperreactivity	-0.02	-0.22	0.83	0.17	0.03	0.03
		Visual Reception	0.00	0.00	0.89	0.38		Visual Reception	0.00	0.76	0.45			
		Expressive Language	0.00	0.00	0.87	0.39		Expressive Language	0.00	0.85	0.40			
	Seeking	Seeking	0.15	0.07	2.16	**0.03**	1	Seeking	0.04	0.98	0.33	0.11	0.01	____
		Group	0.35	0.23	1.52	0.13								
		Group X Seeking	-0.11	0.08	-1.39	0.17	2	Seeking	0.07	1.73	0.09	0.26	0.07	0.05
		Visual Reception	0.01	0.00	1.54	0.13		Visual Reception	0.00	1.15	0.25			
		Expressive Language	0.01	0.00	1.70	0.09		Expressive Language	0.00	1.32	0.19			
SEQ (Parent Report)	Hyporeactivity	Hyporeactivity	0.05	0.09	0.56	0.57	1	Hyporeactivity	-0.07	-1.32	0.19	0.15	0.02	____
		Group	0.34	0.22	1.54	0.13								
		Group X Hyporeactivity	-0.15	0.10	-1.46	0.15	2	Hyporeactivity	-0.05	-1.04	0.30	0.20	0.04	0.02
		Visual Reception	0.00	0.00	0.76	0.45		Visual Reception	0.00	0.76	0.45			
		Expressive Language	0.00	0.00	0.58	0.56		Expressive Language	0.00	0.60	0.55			
	Hyperreactivity	Hyperreactivity	-0.05	0.10	-0.51	0.61	1	Hyperreactivity	0.03	0.47	0.64	0.06	0.00	____
		Group	-0.21	0.27	-0.79	0.44								
		Group X Hyperreactivity	0.12	0.13	0.95	0.35	2	Hyperreactivity	0.03	0.40	0.69	0.17	0.03	0.03
		Visual Reception	0.00	0.00	0.98	0.33		Visual Reception	0.00	0.76	0.45			
		Expressive Language	0.00	0.00	0.84	0.41		Expressive Language	0.00	0.84	0.40			
	Seeking	Seeking	-0.07	0.10	-0.75	0.45	1	Seeking	0.01	0.08	0.94	0.01	0.00	____
		Group	-0.24	0.32	-0.75	0.46								
		Group X Seeking	0.11	0.12	0.89	0.38	2	Seeking	0.00	-0.03	0.98	0.16	0.03	0.03
		Visual Reception	0.00	0.00	0.81	0.42		Visual Reception	0.00	0.79	0.43			
		Expressive Language	0.00	0.00	1.00	0.32		Expressive Language	0.00	0.84	0.41			

(continued)

Table 4. (continued)

Variables			Moderation Effects				Main Effects							
			Coefficent	*SE*	*t*	Significance	Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
Canonical	Canonical Directed	Canonical Directed	0.00	0.00	-0.08	0.93	1	Canonical Directed	0.00	1.35	0.18	0.16	0.03	____
		Group	-0.03	0.10	-0.27	0.79								
		Group X Canonical Directed	0.00	0.00	0.73	0.47	2	Canonical Directed	0.00	0.70	0.49	0.21	0.05	0.02
		Visual Reception	0.00	0.00	0.96	0.34		Visual Reception	0.00	0.86	0.39			
		Expressive Language	0.00	0.00	0.71	0.48		Expressive Language	0.00	0.69	0.50			
	Canonical Non-Directed	Canonical Non-directed	0.00	0.01	-0.44	0.66	1	Canonical Non-directed	0.00	-0.18	0.86	0.02	0.00	____
		Group	0.03	0.08	0.39	0.70								
		Group X Canonical Non-directed	0.00	0.01	-0.10	0.92	2	Canonical Non-directed	0.00	-0.60	0.55	0.21	0.04	0.04
		Visual Reception	0.00	0.00	0.96	0.34		Visual Reception	0.00	0.92	0.36			
		Expressive Language	0.00	0.00	1.18	0.24		Expressive Language	0.00	1.22	0.23			
Non-Canonical	Non-Canonical Directed	Non-canonical Directed	0.00	0.00	1.33	0.19	1	Non-canonical Directed	0.00	1.37	0.17	0.16	0.03	____
		Group	0.12	0.13	0.96	0.34								
		Group X Non-canonical Directed	0.00	0.00	-0.91	0.36	2	Non-canonical Directed	0.00	1.02	0.31	0.23	0.05	0.03
		Visual Reception	0.00	0.00	0.98	0.33		Visual Reception	0.00	0.97	0.33			
		Expressive Language	0.00	0.00	0.75	0.45		Expressive Language	0.00	0.73	0.47			
	Non-Canonical Non-Directed	Non-canonical Non-directed	0.00	0.01	0.37	0.71	1	Non-canonical Non-directed	0.01	0.77	0.45	0.09	0.01	____
		Group	0.02	0.09	0.20	0.84								
		Group X Non-canonical Non-directed	0.00	0.01	0.30	0.76	2	Non-canonical Non-directed	0.00	0.70	0.49	0.22	0.05	0.04
		Visual Reception	0.00	0.00	0.95	0.35		Visual Reception	0.00	0.87	0.39			
		Expressive Language	0.00	0.00	1.13	0.26		Expressive Language	0.00	1.11	0.27			

(continued)

Table 4. (continued)

Variables			Moderation Effects				Main Effects							
			Coefficent	*SE*	*t*	Significance	Model	Variables	*B*	*t*	Sig.	R	R Square	R Square Change
Other Vocalizations	Atypical Vocalizations	Atypical	-0.01	0.01	-1.69	0.10	1	Atypical	-0.01	-2.09	**0.04**	0.24	0.06	____
		Group	0.01	0.10	0.06	0.95								
		Group X Atypical	0.00	0.01	0.62	0.54	2	Atypical	-0.01	-1.98	0.05	0.30	0.09	0.03
		Visual Reception	0.00	0.00	1.13	0.26		Visual Reception	0.00	0.89	0.38			
		Expressive Language	0.00	0.00	1.10	0.28		Expressive Language	0.00	1.02	0.31			
	Distress Vocalizations	Distress	0.00	0.00	-0.30	0.76	1	Distress	0.00	-0.80	0.43	0.09	0.01	____
		Group	0.04	0.10	0.43	0.67								
		Group X Distress	0.00	0.00	-0.22	0.83	2	Distress	0.00	-0.59	0.55	0.21	0.04	0.04
		Visual Reception	0.00	0.00	0.95	0.35		Visual Reception	0.00	0.86	0.39			
		Expressive Language	0.00	0.00	1.01	0.32		Expressive Language	0.00	1.06	0.29			
	Pleasure Vocalizations	Pleasure	0.00	0.01	-0.02	0.98	1	Pleasure	0.01	1.33	0.19	0.15	0.02	____
		Group	-0.03	0.08	-0.35	0.73								
		Group X Pleasure	0.02	0.02	1.33	0.19	2	Pleasure	0.01	1.04	0.30	0.23	0.05	0.03
		Visual Reception	0.00	0.00	0.99	0.33		Visual Reception	0.00	0.82	0.42			
		Expressive Language	0.00	0.00	1.07	0.29		Expressive Language	0.00	0.98	0.33			

Note. Models 1 and 2 represent effects before and while controlling for visual reception and expressive language. SPA = Sensory Processing Assessment; SEQ = Sensory Experiences Questionnaire. Bolded entries highlight significant results.

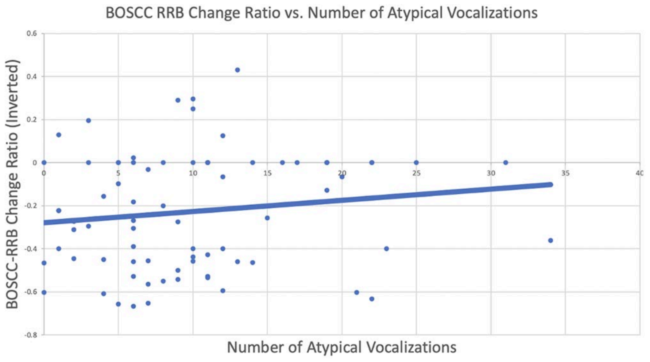

Figure 4. BOSCC RRB change ratio versus number of atypical vocalizations.

vocalizations were a significant predictor of BOSCC-RRB-ratio ($\beta = -0.007$, $t = -2.087$, $p = .04$). When controlling for VR and EL, atypical vocalizations fell just below statistical significance ($\beta = -0.006$, $t = -19.981$, $p = .052$); see Figure 4.

Discussion

Research is limited on child characteristics that impact treatment outcomes. This exploratory study evaluated how child sensory and vocalization patterns predict response to treatment in EL-ASD toddlers. Our results suggest that baseline sensory reactivity and the number of atypical vocalizations predict how much improvement a child will make in social communication skills over the course of 9 months. Child characteristics before the start of treatment, including sensory reactivity and vocalization patterns, may provide early indicators for a child's trajectory in autism symptoms as well as novel treatment targets that can be tailored to a child's baseline presentation.

Research indicates that children with autism display atypical sensory response patterns (Baranek et al., 2006; Ben-Sasson et al. 2009) and these patterns may be present in infancy before a definitive autism diagnosis is currently possible (Sacrey et al., 2015; Turner-Brown et al., 2013; Wolff et al., 2019). This study found that SPA hyporeactivity (e.g., reduced reactivity to sensory stimuli when it is expected) was a significant predictor of BOSCC-SC ratio in the treatment group, and this relationship held true when controlling for baseline VR and EL. This suggests that intervention outcomes for some infants at EL-ASD might be improved by focusing first on addressing sensory reactivity, specifically behavioral orienting to sensory stimuli, before introducing new social communication skills, in at least a subset of children at EL-ASD. Such interventions might include: teaching parents to identify their children's sensory preferences and reactivity patterns, assist their child in tuning to the appropriate sensory stimuli, and ensure that sensory stimuli are optimally salient and meaningful in daily routines. These suggestions may have implications for tailoring the child's sensory environment to encourage optimal levels of engagement as appropriate to the situation, or for tailoring intervention strategies to specifically address sensory hyporeactivity to improve treatment outcome.

Similar results were found when analyzing SPA hyperreactivity results; however, when controlling for baseline VR and EL, SPA hyperreactivity was no longer a significant predictor of BOSCC-SC-ratio (alpha value was just under significance). This may suggest that verbal and nonverbal skills are important to understanding the progress of a child during treatment and/or there may be a relationship between verbal and nonverbal skills and sensory hyperreactivity that impacts later outcome. Alternatively, our limited sample size may limit the power of our results, particularly since the results fell just above our significance threshold. Future research should continue to explore the relationship between sensory hyperreactivity and child SC outcomes, particularly in larger samples and while taking into account verbal and nonverbal skills.

Research has shown that increased atypical vocalizations are associated with diagnostic status, above and beyond baseline verbal and nonverbal skills. The results of this exploratory study suggest that Time 1 atypical vocalizations predicted BOSCC-SC change for children, regardless of group assignment. Other components of vocalizations including canonical (Oller et al., 1999; Paul et al., 2011) and noncanonical (Oller et al., 1994), directed or nondirected, were not significant predictors of changes in social communication symptom change. Although this finding suggests that atypical vocalizations warrant consideration in early intervention for EL-ASD infants and toddlers, we are not aware of any existing intervention research that addresses strategies for, or outcomes of, including these as early intervention targets. Research on the functions of these vocalizations for the children and strategies that adults can use to respond in supportive ways to atypical vocalizations may be useful in further clarifying the clinical implications of this finding.

Early intervention trials of toddlers with ASD diagnoses have begun to examine baseline child and parent characteristics that impact changes in response to treatment (Beglinger & Smith, 2005; Carter et al., 2011; Kasari et al., 2010; Oosterling et al., 2010; Rogers et al., 2012; Zachor et al., 2007) (joint attention; Olafsen et al., 2006; Watson et al., 2013). For example, child object interest (Fossum et al., 2018) and IQ (Grzadzinski et al., under review; Harris & Handleman, 2000) at baseline have been linked with an amount of improvement over the course of an intervention. These results add to this growing literature suggesting that in a sample of children with early increased likelihood of later ASD behaviors that may present presymptomatically, such as sensory hyporeactivity and atypical vocalizations, could be crucial to tailoring early intervention practices such that future treatments are more effective. Identifying these prediagnostic markers provides targets for a potential very early (before 12 months) presymptomatic intervention for EL-ASD children. Future research should continue to evaluate child and family characteristics that may be present in infancy and could be targeted in a presymptomatic intervention to promote optimal developmental trajectories.

As these results suggest that behaviors such as sensory hyporeactivity and atypical vocalizations may be present presymptomatically (or at least prior to symptom consolidation into a diagnosable condition), further exploration of presymptomatic treatment and intervention practices is necessary. Currently, clinical practices do not focus on presymptomatic intervention for autism. Implementing presymptomatic intervention that is specifically tailored to certain features, such as sensory hyporeactivity and atypical vocalizations, could be crucial to promoting better adaptive outcomes in infants and toddlers who are particularly likely to make slow progress in social communication and language skills. Presymptomatic intervention could improve future functional behavior, and lessen the severity of impairments.

The current study has several limitations, and the results should be considered in light of these. After careful consideration, given the vastly exploratory nature of the original research question, a decision was made to not control for multiple comparisons to ensure that possible significant findings were not missed. If the decision had been made to control for multiple comparisons by using a more stringent alpha level, for example, the primary results of this manuscript would remain unchanged (impact of atypical vocalizations on amount of SC change). That said, future studies with larger samples should examine these variables with more robust alpha criteria. The sample size is relatively small, and the majority of the sample consisted of white male children with highly educated parents despite attempting to be representative of the larger local community (See Table 1). These results may not be successfully extrapolated to more diverse populations; thus, future work would benefit from larger, more diverse samples. The results surrounding the atypical vocalizations may be particularly limited due to the use of only one measure of nuanced vocalizations; however, given the intricacy of coding 30 min of vocalizations, examining the predictive value of early vocalizations for outcomes in this population is a valuable contribution. The observational measures used in this work (SPA, vocalizations coding, and BOSCC) use brief samples of child behavior that intend to represent broader, pervasive characteristics, although these limited snapshots may not be fully representative of a particular child's skills in these areas. It is also important to note that we only have two timepoints to evaluate treatment-related change (pre- and post-treatment); this limits the interpretation of results as we cannot evaluate trends over time or regression to the mean. Future studies would benefit from the use of multiple measurements across more than 2 time points. The results of the work focused on direct observation (SPA) showed a relationship between Sensory Hyporeactivity and BOSCC-SC Ratio; however, this same relationship was not present for the parent-reported hyporeactivity (SEQ). These results could be limited due to the obstacles parents face when attempting to characterize hyporeactive behavior—that is, the absence of a response may be more difficult to recognize than the presence of an "over-response." Clinicians may also observe certain behaviors when administering specific stimuli under more controlled conditions, but the same behaviors may be less evident outside of a clinical environment if, for example, the child functions more adaptively within predictable home routines. While parent reports on the SEQ questionnaire may be a broader and more ecologically-valid way to capture some aspects of sensory reactivity in daily routines, it is also possible that there is variability in the parent's ability to accurately report these behaviors in such a young sample. For example, interpretation or understanding of these behaviors may be based on parental experience such as experience raising older siblings or opportunities to observe their own child in relation to same-age peers. Research has shown that parents who are reporting on the later-born sibling of a child with autism indicate the sibling has fewer atypical sensory behaviors on the SEQ than parents who are reporting on the sibling of a typically developing child (Wolff et al., 2019), suggesting that parents of high familial likelihood siblings interpret the questions on the SEQ differently and in light of (or in comparison with) their experience of a child with autism. Although this sample was a community sample, and not a familial likelihood group, these types of discrepancies in parental experiences could be considered in future studies. Using a variety of measures, these analyses examined the impact of child characteristics, specifically sensory reactivity and atypical vocalizations, on treatment outcome in children with or at elevated likelihood for autism. These results of this exploratory study indicate that sensory hyporeactivity and atypical vocalizations should be further studied as potentially important characteristics to focus on when tailoring interventions to ensure that they are maximally effective for children with elevated likelihood for autism.

Overall, this initial work provides a stepping stone for future studies to examine baseline child characteristics as predictors of early intervention outcomes. Specifically, a child's baseline vocalization patterns (e.g., number of atypical vocalizations) as well as sensory reactivity may have significant implications for the amount of improvement to expect over the course of an intervention. As such, determinations about utility of an intervention may need to be adjusted based on each child's baseline behaviors. Similarly, treatment goals and behavior targets may need to be determined based on a child's profile; for example, a child who often is hyporeactive to the social and nonsocial stimuli in the environment may benefit from caregivers or interventionists increasing the salience of stimuli or selecting activities and stimuli that have been previously observed to engage the child's interest and attention. . This work introduces novel questions to the field of early intervention research, highlighting the need for additional examinations of baseline skills/ characteristics as researchers interpret the value of intervention practices.

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