HHS Public Access
Author manuscript
Autism Res. Author manuscript; available in PMC 2022 September 01.

Published in final edited form as:
Autism Res. 2021 September ; 14(9): 2027–2037. doi:10.1002/aur.2557.

Parent Responsiveness Mediates the Association between Hyporeactivity at Age One Year and Communication at Age Two Years in Children at Elevated Likelihood of ASD

Rebecca Grzadzinski[1,2], **Sallie W. Nowell**[3], **Elizabeth R. Crais**[1,4], **Grace T. Baranek**[1,5], **Lauren Turner-Brown**[1,6], **Linda R. Watson**[1,4]

[1]Program for Early Autism Research, Leadership, and Service (PEARLS), University of North Carolina at Chapel Hill, NC

[2]University of North Carolina, Carolina Institute for Developmental Disabilities, Chapel Hill, NC

[3]University of North Carolina, Frank Porter Graham Child Development Institute, Chapel Hill, NC

[4]University of North Carolina, Division of Speech and Hearing Sciences

[5]The Mrs. T. H. Chan Division of Occupational Science and Occupational Therapy, University of Southern California, Los Angeles, CA

[6]University of North Carolina, TEACCH Autism Program, Chapel Hill, NC

Abstract

Studies suggest that lower parent responsiveness is associated with decreased child language abilities. Infants and toddlers later diagnosed with autism spectrum disorder (ASD) often display hyporeactivity to sensory stimuli, which has also been associated with lower child communication abilities and lower parent responsiveness. Yet, whether parent responsiveness mediates the relationship between child hyporeactivity and later communication outcomes remains unexplored. This study is a secondary data analysis of Watson et al. (2017) which includes children (n=83; 56 males) identified via screening as at elevated likelihood of later ASD. Children completed an observational measure of sensory reactivity and a standard developmental assessment at 14 (Time 1) and 23 months old (Time 2). At each time point, parents reported on the child's adaptive communication behaviors and sensory behaviors, and Parent Verbal Responsiveness (AvgPVR) was coded from parent-child free-play videos. Results indicated that the association between child sensory hyporeactivity at Time 1 (observed and parent-reported) and communication at Time 2 (observed and parent reported) was significantly mediated by AvgPVR. Although child hyporeactivity predicts poor communication outcomes, increased parent verbal responsiveness may attenuate this negative impact. Parent responsiveness, a focus of many parent-mediated

Correspondence concerning this article should be addressed to: Rebecca Grzadzinski, PhD, Carolina Institute for Developmental Disabilities (CIDD), University of North Carolina at Chapel Hill, 101 Renee Lynne Court, Carrboro, NC, 27510, Rebecca_grzadzinski@med.unc.edu, Telephone: 919-843-5437, Fax: 919-843-3825.

Conflict of Interest: Authors do not have conflict of interest to report with regard to this study.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

interventions, may be an important mechanism of treatment response that should be directly tested in future research.

Lay Abstract

Toddlers at elevated likelihood of autism spectrum disorder (ASD) are often under-reactive (hyporeactive) to sensory stimuli. This hyporeactivity slows learning of communication skills and provides parents with fewer opportunities to respond to their children. In this study, children with more hyporeactivity at 14 months generally had poorer communication at 23 months; however, the more responsive their parents were, the weaker the relationship between early hyporeactivity and later communication. Thus, increasing parent responsiveness may lead to better communication outcomes for toddlers with the early ASD symptom of hyporeactivity.

Background

Recent studies have begun to explore child and parent characteristics that are associated with child outcomes in an effort to better understand child trajectories and improve tailored treatments for children with autism spectrum disorder (ASD; Green et al., 2015; Pellecchia et al., 2016; Schreibman, et al., 2009; Siller et al., 2013; Venker et al., 2012; Tamis-LeMonda et al., 2001; Warren et al., 2010; Watson et al., 2017). Atypical sensory reactivity patterns are often seen in children with or at elevated likelihood of ASD (Ben-Sasson et al., 2007; Wolff et al., 2019). Hyporeactivity is defined as decreased, delayed, or lack of reaction to sensory stimuli when it would be expected. Hyporeactivity can be observed in response to both social (e.g., hearing their name called, being tapped on the shoulder) and nonsocial (e.g., seeing flashing lights, hearing a siren) stimuli and across sensory modalities (e.g., tactile, auditory, visual). Hyporesponsivity has specifically been linked to child communication abilities (Baranek et al., 2013; Patten et al., 2013; Philpott-Robinson et al., 2016; Watson et al., 2011). In one study, higher hyporeactive scores (which indicate lower child response to sensory stimuli presented) were seen in children with ASD who were not using spoken language compared to children with ASD who were using spoken language (Patten et al., 2013). In another study, higher hyporeactivity to sensory stimuli was associated with lower language skills in children with ASD as well as children with other developmental disabilities (Watson et al., 2011). This finding suggests that early sensory hyporeactivity may predict later child communication abilities and ultimately provide insights into factors impacting interventions or developmental outcomes.

Among parent characteristics, responsiveness has been extensively demonstrated to predict child outcomes, including cognitive, adaptive, language and communication skills, and ASD symptom severity (Pickles et al., 2015; Siller et al., 2013; Venker et al., 2012; Tamis-LeMonda et al., 2001; Warren et al., 2010; Watson et al., 2017). Parent responsiveness can be defined as predictably and contingently responding to a child's communication cues, following a child's attention, and providing related verbal input (McDuffie & Yoder, 2010). Interestingly, increased sensory hyporeactivity in children (common in young children with ASD, as mentioned earlier) is associated with lower parent responsiveness (Kinard et al., 2017), possibly because children who demonstrate sensory hyporeactivity provide less explicit opportunities for their caregivers to respond, and, in turn, parents reduce their responsiveness over time to less reactive infants (Venker et al., 2012; Yoder & McDuffie, 2006). Building on findings of Kinard et al. (2017) using data from the same sample (see parent study, Watson et al., 2017) collected at an earlier time point, we focused on sensory hyporeactivity in this study rather than the other two aspects of child sensory responsiveness (hyperreactivity and sensory seeking behaviors), which have fewer known associations with parent responsiveness.

Research shows that intervention can increase parent responsiveness across a variety of populations, including parents of children with ASD (Siller et al., 2013; Venker et al., 2012; Watson et al., 2017). Indeed, higher parent responsiveness is associated with better child communication and language abilities both in children with and without ASD (Carpenter et al., 1998; Haebig et al., 2013a; 2013b; Levickis et al., 2018; Siller et al., 2013; Tamis-LeMonda et al., 2001; Warren et al., 2010; Watson, 1998). For example, in a sample of typically developing infants, parent responsiveness at 9 and 13 months significantly predicted children's acquisition of language milestones through 21 months of age (Tamis-LeMonda et al., 2001). Higher parent responsiveness is also associated with improved child language outcomes in samples of children with Fragile X syndrome (Warren et al., 2010), as well as children with ASD (Siller & Sigman, 2008; Yoder et al., 2015). Though studies of parent responsiveness often emphasize the role of the parent, parent-child interaction patterns are broadly assumed to reflect a dyadic, transactional process (Haebig et al., 2013a; 2013b; Siller & Sigman, 2008; Tamis-LeMonda et al., 2001).

Given that parent responsiveness is often a focus in parent-mediated interventions for children with or at elevated risk for ASD (Baranek et al., 2015; Green et al., 2015; Kasari et al., 2014; Siller et al., 2014; Watson et al., 2017; Whitehouse et al., 2019), testing the extent to which parent responsiveness may mediate the association between early child hyporeactivity and later communication skills provides an opportunity to understand a possible mechanism of change in treatment (Lerner et al., 2012; Vivanti et al., 2014). This research can help the field better understand the complex, dynamic interplay between infants and their caregivers and assist in the development of tailored interventions for children at-risk. Testing this potential mediating role of parent responsiveness was the overarching goal of this work.

To reach this goal, we conducted a secondary data analysis of Watson et al. (2017). We first tested a mediation model using *observation-based, clinician-administered measures* of child hyporeactivity (the Sensory Processing Assessment; SPA; Baranek, 1999a; Baranek et al., 2007, 2013) and communication outcomes (the Mullen Scales of Early Learning; MSEL; Mullen, 1995). Second, we tested a replication model using *parent report measures* of child hyporeactivity (the Sensory Experiences Questionnaire Version 2.1; SEQ; Baranek, 1999b; Baranek et al., 2006; Little et al., 2011) and communication outcomes (the Vineland Adaptive Behavior Scales, Communication Domain; VABS; Sparrow, Cicchetti, & Balla, 2005). Consistency of results across different formats (e.g., parent-report versus clinically observed measures) can provide information about the reliability of this phenomenon as well as methods for future research exploring similar relationships.

Method

Participants.

Eighty-seven children and their caregivers were enrolled in an early intervention trial (see Watson et al., 2017) from which data for the current study were drawn. Children were eligible for the trial if scores on the First Year Inventory 2.0 (FYI 2.0; Baranek et al., 2003) at 12 months of age indicated elevated risk for ASD (Watson et al., 2017). All caregivers completed written informed consent as approved by the Institutional Review Board (IRB) at the University of North Carolina. Additional eligibility criteria included birthweight >2500g and English spoken as a primary language at home.

Of the original 87 children with elevated FYI scores at 12 months, 83 completed the intervention trial, including an assessment approximately 10 months after initial screening. The current study includes 83 children (56 males) seen at two time points: age 14 months (Time 1) and age 23 months (Time 2). Forty-five (54%) children were randomized to an intervention (Adaptive Responsive Teaching; ART), while the remainder were assigned to a “Referral to Early intervention and Monitoring” group (REIM; Watson et al., 2017). There were no main effects on children’s sensory reactivity or communication skills in the treatment study, but parents in ART showed increased parent responsiveness compared to REIM. Assignment group (ART and REIM) was controlled for in all analyses. See Table 1 for background and demographic information at Time 1 and Time 2. Follow-up assessments for a subset of children (n=57; n=33 from ART group) were completed between the ages of 3 and 5 years old, with sufficient information to assign definitive diagnoses for 53 children. Of these 53 children, 18 (34%) had diagnoses of ASD at preschool follow-up.

Measures.

See Figure 1 for information on measures administered at Time 1 and Time 2.

Eligibility: The First Year Inventory, v. 2.0 (FYIv2.0; Baranek et al., 2003) is a 63-item parent report questionnaire normed on a community sample of 1300 12-month-olds (+/− 2 weeks; Reznick et al., 2007). The FYIv2.0 assesses early symptoms associated with later ASD diagnosis in two domains: social-communication and sensory-regulatory. Children who meet the dual cut-off criteria (≥94%ile for risk in the social-communication domain and ≥88%ile in the sensory-regulatory domain) have approximately a 31% likelihood of an ASD diagnosis by preschool age (Turner-Brown, Baranek, Reznick, Watson, & Crais, 2013), and an 85% likelihood of having some type of developmental disability or concern (including ASD).

Autism Symptoms.—As a metric of autism symptoms, the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2012) was administered to children at Time 2 and to 45 of the 57 children who participated in follow-up assessments between the ages of 3 and 5 years old (“preschool follow-up”). The ADOS yields an overall calibrated severity score (CSS; Gotham et al., 2009) as well as separate calibrated severity scores for the social affect domain (CSS SA) and the restricted, repetitive behavior domain (CSS RRB; Hus et al., 2014). Descriptive information about Time 2 ADOS CSS, CSS SA, and CSS RRB is presented in Table 1. At preschool follow-up, ADOS CSS, CSS SA, and CSS RRB had means of 3.84 (SD=2.65), 3.78 (SD=2.57), and 5.78 (2.90), respectively. ADOS CSS scores above 4.0 are primarily seen in individuals with ASD diagnoses (Gotham et al., 2009).

Cognitive.—The Mullen Scales of Early Learning (MSEL; Mullen, 1995) was administered to children at Time 1 and Time 2. The MSEL yields standard scores (T-scores; mean = 50, SD = 10) for fine motor, visual reception, receptive language, and expressive language scales. An average of T-scores for expressive language and receptive language scales at Time 2 (MSELLangAvg) was used as an outcome variable in mediation analyses. The average of expressive language and receptive language was chosen due to conceptual alignment with the communication domain of the VABS (see below).

Sensory Reactivity.—The Sensory Processing Assessment for Young Children (SPA; Baranek, 1999a; Baranek et al., 2007, 2013) is a 20-minute play-based observational measure appropriate for children between 6 months and 9 years of age. Results of the SPA yield scores in three constructs: Sensory Hyporeactivity, Sensory Hyperreactivity, and Sensory Seeking behaviors. The SPA has been found to have high inter-rater reliability and strong convergent validity with other measures of sensory processing (Baranek et al., 2007, 2013). The construct of interest in this study is the Sensory Hyporeactivity score (predictor variable in analyses), which ranges from 1-5 and is generated from a series of presses assessing whether the child orients to social and nonsocial stimuli across three modalities (tactile, auditory and visual; see Baranek et al., 2013). All examiners were trained to reliability of scoring and fidelity of administration prior to the start of the study. At the outset of the study, 20% of SPA videos were coded for reliability from video. Some raters were not meeting standards despite monthly skills labs/booster sessions. Therefore, all videos were scored by three raters (primary, reliability, and a third master coder to resolve discrepancies) and a consensus score was determined for every video.

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 et al., 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: Sensory Hyporeactivity, Sensory Hyperreactivity, and Sensory Seeking behaviors, across modalities. The factors of the SEQ have been validated using Confirmatory Factor Analysis (CFA; Ausderau et al., 2014; Watson et al., 2011). The SEQ also has high test-retest reliability (Little et al., 2011) and internal consistency (Baranek et al., 2006). Hyporeactivity from the SEQ was also tested as a predictor variable in replication mediation analyses.

Adaptive Functioning.—The Vineland Adaptive Behavior Scales (VABS; Sparrow et al., 2005) Caregiver Interview was completed with the caregiver(s) of all children at Time 1 and Time 2. The VABS provides standard scores for adaptive functioning in the domains of socialization, communication, daily living, and motor skills, with lower scores indicating greater impairment. The VABS has demonstrated strong reliability and validity (Sparrow et al., 2005). The VABS Communication scale measures a combination of receptive and expressive communication and was included as an outcome variable in the replication mediation analysis model.

Parent Responsiveness.—A metric of parent verbal responsiveness (PVR) was generated using the Parent Responsiveness Coding System (PRCS) adapted from Yoder et al. (2015). Coding was completed using 10-minute videotaped caregiver-child free-play interactions gathered at Time 1 and Time 2. Research assistants (blind to the child's assignment group) coded the videos using partial interval coding (5 second intervals) for (a) codability (e.g., child and parent were visible on screen), (b) child lead (e.g., child looked at and/or touched a referent object), and (c) parent response to child lead (e.g., the parent talked about the child's referent object or activity). Using the PRCS, PVR was defined as the percent of intervals in which the parent gave a follow-in verbal response to the child's lead (object or activity on which the child's attention was focused). An average percent of PVR (AvgPVR) across Time 1 and Time 2 was calculated [(PVR Time 1 + PVR Time 2)/2]. We judged AvgPVR to be the most accurate representation of a child's exposure to parent verbal responsiveness between Time 1 and Time 2 (the hypothesized timeframe in which a mediation effect would occur) as it aggregated data across both time points.

Data Analysis

Primary Analyses.

First, correlations between SPA Hyporeactivity, MSELLangAvg, and AvgPVR were calculated (See Table 2). Second, mediation analyses were conducted using PROCESS v3.1 (http://www.afhayes.com) in order to assess the mediating effect of AvgPVR on the relationship between child hyporeactivity on the SPA at Time 1 and MSELLangAvg at Time 2. PROCESS is a free software macro for SPSS that estimates direct and indirect effects in regression models, allowing researchers to determine "when" and "how" relationships exist within their data (Hayes, 2017). PROCESS Model 4 was used for each of our mediation analyses with intervention group assignment as a covariate in each path of the model. PROCESS also allows for bootstrap estimation of these indirect effects which is essential for answering mediation questions and determining the stability of results in social sciences samples, which are often underpowered. Bootstrapped analyses were performed to address potential concerns about normality. To assess the mediation effect in each model, the indirect effect was tested using a bootstrap estimation approach with 10,000 samples.

Replication Analyses.

The SEQ was used as a measure of child hyporeactivity at Time 1 in order to confirm the results of the primary analyses (See Table 2). First, correlations between SEQ Hyporeactivity, VABS Communication, and AvgPVR were calculated. Second, mediation analyses were conducted consistent with method above to assess the mediating effect of AvgPVR on the relationship between child hyporeactivity on the SEQ at Time 1 and VABS

Communication at Time 2. Consistent with Primary Analyses (see above), the indirect effect was tested using a bootstrap estimation approach with 10,000 samples.

Results

Across both primary and replication analyses, assignment group was included in all analyses, though no significant effects were found for the assignment group variable.

Primary analyses.

SPA Hyporeactivity at Time 1 was a significant predictor of AvgPVR, $b=-5.26$, SE= 2.00, $p<0.05$, and Average Parent Verbal Responsiveness was a significant predictor of MSELLangAvg at Time 2, $b=0.26$, SE=0.06, $p<0.001$. The significant association between SPA Hyporeactivity at Time 1 and MSELLangAvg at Time 2, $b=-2.65$, SE=1.13, $p<0.05$, was no longer present when including AvgPVR as a mediator in the analyses, $b=-1.27$, SE=1.05, $p=0.23$. Approximately 27% ($R^2=0.27$) of the variance in MSELLangAvg at Time 2 was accounted for by the predictors. The indirect coefficient was significant, $b=-1.37$, SE=0.59, 95% CI=−2.57, −0.27. See Figure 2.

Replication analyses.

Results indicated that SEQ Hyporeactivity at Time 1 was a significant predictor of Average Parent Verbal Responsiveness, $b=-9.26$, SE=2.46, $p<0.001$, and AvgPVR was a significant predictor of VABS Communication at Time 2, $b=0.26$, SE=0.09, $p<0.01$. The magnitude of the association between SEQ Hyporeactivity at Time 1 and VABS Communication at Time 2, $b=-8.14$, SE=2.16, $p<0.001$, was lessened when including AvgPVR as a mediator in the analyses, $b=-5.69$, SE=2.25, $p<0.05$. Approximately 23% ($R^2=0.23$) of the variance in VABS Communication at Time 2 was accounted for by the predictors. The indirect coefficient was significant, $b=-2.45$, SE=1.18, 95% CI=−4.86, −0.32. See Figure 3.

Post-Hoc Analyses

In order to assess whether the effects on child outcome were specific to the communication domain, we conducted correlations to evaluate the association between SPA Hyporeactivity at Time 1 and the MSEL Visual Reception and Fine Motor scale scores at Time 2. Results indicated that there was not a statistically significant association between SPA Hyporeactivity and MSEL Visual Reception (−0.13, $p=0.26$) or SPA Hyporeactivity and MSEL Fine Motor (−0.16, $p=0.16$). Therefore, additional mediation analyses were not conducted.

See Supplemental Materials for results of post-hoc analyses exploring the relationship between AvgPVR, child communication (VABS communication), and parent education level (as a proxy of socioeconomic status; SES).

Discussion

Our results support the concept that a dynamic relationship between child and parent variables impacts child communication outcomes. This is consistent with results of other studies (Haebig et al., 2013a; 2013b; Siller & Sigman, 2008; Tamis-LeMonda et al., 2001), but within a community sample with early parent-reported symptoms associated with ASD. Often research studies emphasize the impact of parents on their children's language development; e.g. children from lower socioeconomic status, whose parents expose them to fewer words, and those with depressed parents, whose parents are less responsive to them, demonstrate lower language abilities (Cycyk et al., 2015; Hart & Risley, 1995; Ryff & Keyes, 1995). Our study suggests that the association between parent characteristics and child communication outcomes may be only one piece of a more complex picture in which child characteristics and subsequent dyadic qualities also impact later outcomes. In addition, while parent education and socioeconomic status have been linked to child communication outcomes (Chow et al., 2017; Law et al., 2018; Playford et al., 2017), these parental variables are not easily modified via intervention. In contrast, parent verbal responsiveness may provide a specific intervention target that is modifiable and mediates the association between parent education and child communication. Future studies are needed to conduct a more rigorous test of this theory which would require (1) a moderated mediation model with intervention group as the moderator with the hypothesis being that the mediation effect is attenuated in the experimental, compared to the control condition, and (2) that the mediator (parent verbal responsiveness) is specified in a way that it represents a change-score and is measured prior to the outcome. Our findings are also encouraging, indicating that child characteristics are not unidirectional determinants of communication outcomes and that parent responsiveness may mitigate the negative consequences of child characteristics. Furthermore, future research should examine other combinations of separate child and parent characteristics, as well as dyadic characteristics (e.g., engagement), that may impact child outcomes, and could further facilitate more tailored interventions for young at-risk children (Kasari et al., 2014).

Though this study did not specifically test treatment-related changes in parent responsiveness, understanding the role of parent responsiveness and its impact on child outcomes can help in determining possible key treatment ingredients (Lerner et al., 2012; Vivanti et al., 2014), particularly since many early interventions targeting communication outcomes use parent-mediated models in which parents are active participants in implementing treatment strategies (Ferjan Ramírez et al., 2019; Ramírez et al., 2020; Schreibman et al., 2015). Parent-mediated intervention models are constructed on the premise that children spend most of their time with their caregivers, and child learning opportunities can be maximized by teaching parents how to implement strategies during daily routines (Schreibman et al., 2015). Yet, research has lagged in understanding specific mechanisms that may underlie treatment outcomes in these interventions (Lerner et al., 2012; Kasari, 2002; Vivanti et al., 2014), particularly since comprehensive intervention programs target a range of skill areas, making it difficult to identify specific mechanisms that lead to change (Lord et al., 2005). Given that child outcomes are highly variable in response to interventions, there is a need to understand the specific mechanisms of change in order to tailor interventions effectively (Lerner et al. 2012; Vivanti et al., 2014).

The implications of this work may be of particular relevance to the ASD research community since young children with ASD, or at elevated likelihood of developing ASD, often display extreme hyporeactivity to sensory stimuli (Baranek et al., 2006; Ben-Sasson et al., 2008; Rogers & Ozonoff, 2005). The children included in this study were at elevated likelihood for developing ASD, based on risk assessment from an ASD screening measure (the FYI). In addition, results of diagnostic assessments on a subsample of children seen between 3 and 5 years old indicated that around one-third of the sample received a diagnosis of ASD, and that mean symptom severity scores approached the threshold value for CSS SA associated with ASD diagnoses and exceeded the threshold for CSS RRB. These data align with clinical observations that many of the children at preschool age who did not meeting full diagnostic criteria for ASD nevertheless showed notable ASD symptoms. In studies of children with ASD, parent responsiveness has been shown to be related to improved communication outcomes for children (McDuffie & Yoder, 2010; Siller et al., 2013; Siller & Sigman, 2002; 2008; Watson et al., 2017) while child hyporeactivity to sensory stimuli has been linked to poorer communication outcomes (Patten et al., 2013; Watson et al., 2011). This work adds to the literature by elucidating the link between child characteristics (sensory hyporeactivity), parent characteristics (responsiveness), and later child outcomes (communication). When developing interventions that focus on improving parent responsiveness, researchers may wish to target recruitment toward children with hyporeactivity to sensory stimuli, who are vulnerable to poor language outcomes and may especially benefit from increased parent responsiveness. As such, these results may provide insights to the community researchers examining ASD phenotypes and the development of effective ASD interventions.

This study highlights that, although children may have certain early developmental characteristics, such as hyporeactivity to sensory stimuli, that are associated with poorer communication outcomes (Watson et al., 2011; Patten, et al., 2013), parental style of interaction may reduce the effect of these characteristics on later communication outcomes. This is an empowering message to parents and treatment providers, especially given evidence that parent responsiveness can be increased over the course of intervention (Green et al., 2015; Siller et al., 2013; Venker et al., 2012; Watson et al., 2017). In addition, the lack of significant correlations between SPA Hyporeactivity and non-verbal domains of cognitive functioning highlights the implications of our findings for child communication outcomes specifically.

The consistency between results using different formats and contexts, across both observational, lab-administered measures (SPA and MSEL) and parent reports of home behaviors (SEQ and VABS), highlights the integrity of these results. Although this work promotes the use of multiple methods to confirm results, the consistency in our findings can also support decision-making for researchers who identify particular benefits to using one type of measure of these constructs over another in future studies. For example, the use of direct observation measures may eliminate bias associated with parent report, though use of parent report may be more feasible in clinical settings, in research studies with limited funding or when researchers are concerned about reducing the length of direct child assessments.

Though our measures were not temporally sequenced with a measure of parent responsiveness between hyporesponsiveness and communication, the results of this work provide some evidence that parent responsiveness may be one possible mechanism, through which parent-mediated interventions may be effective. This is of particular value since parent responsiveness has been shown to be malleable in multiple intervention trials for children diagnosed with ASD or showing early symptoms of ASD (Baranek et al., 2015; Green et al., 2015; Siller et al., 2013; Venker et al., 2012; Watson et al., 2017). Some work has shown significant mediating effects of improvements in parent responsiveness on child treatment response (Watson et al., 2017); however, future intervention research with new samples is needed to confirm the mediating role of parent responsiveness, especially changes in parent responsiveness over the course of a parent-mediated treatment, on later child communication skills.

Limitations

These results should be interpreted in light of several limitations. The sample size in this study, although adequately powered for our analyses, could be expanded in future studies to allow for more complex statistical explorations of additional variables. As a secondary data analysis, this sample (Watson et al., 2017) was not collected for the purpose of testing mediation or moderated mediation and thus, we were somewhat limited in the analyses we could run and the questions we could answer. For instance, we controlled for the main effect of intervention group assignment but we were not powered to control for all of the possible indirect effects of this and other important variables (e.g., parent education) due to our sample size.

Specifically, our mediation analyses were limited by this being a secondary data analysis in that (1) that the mediation model was tested in a clinical trial that targeted the mediator (parent verbal responsiveness), and (2) that the mediation model was specified in ways that did not establish the temporal order precedence of the mediator. Since parent verbal responsiveness was the target of the intervention between Time 1 and Time 2, it would be ideal to run a moderated mediation model testing the intervention group as a 4^{th} variable rather than as a covariate. Moderated mediation, which is possible using PROCESS model 59 (Hayes, 2017), is a more rigorous way of controlling for group assignment because it controls within each interaction effect of the model in addition to the main effect. This model requires hundreds of participants per group; thus, our sample size was too small to run this moderated mediation model. We controlled for group assignment to the best of our ability (by controlling for it in the main effects of the model) and the results should be interpreted in light of this limitation. Furthermore, although we used the mean Time 1 and Time 2 parent verbal responsiveness to approximate parent verbal responsiveness experienced between Time 1 and Time 2, an important limitation is the lack of a direct measure of parent verbal responsiveness temporally situated between the measures of hyporeactivity and language/communication outcomes. Temporally sequenced measurements would have allowed more confident interpretation of the mediation model. Future research is needed with larger sample to replicate our findings with these more rigorous mediation models and temporal sequencing.

Although all of the children in the study were identified through screening as at elevated risk for ASD, the lack of diagnostic outcome information on a large proportion of the sample (40%) limits our capacity to evaluate whether the mediation effects are similar for children with and without later ASD diagnoses. However, it is worth noting that among those with diagnostic outcomes, 34% of the children were identified with ASD. Another limitation is that the results of this study may not generalize to different samples because the families in this sample were predominantly White (though representative of the local racial demographics), English-speaking, and highly educated.

This study focused on one construct of sensory reactivity—hyporeactivity—given the literature in support of the relationship between sensory hyporeactivity and child communication outcomes (Patten et al., 2013; Watson et al., 2011) and parent responsiveness (Kinard et al., 2018). Future studies could examine other sensory constructs, including sensory hyperreactivity and sensory seeking in children with ASD as well as parental stress (Ausderau et al., 2016). Many potential aspects of associations between early child sensory reactivity and later child or family outcomes were not explored in the current study. We also focused specifically on parent *verbal* responsiveness, as opposed to more global constructs of responsiveness (including non-verbal) or sensitivity (Siller & Sigman, 2008), which may have a different impact. Of note, this work does not ask the question of "how much" parent verbal responsiveness is sufficient or optimal to promote positive child language outcomes in children who demonstrate varying levels of hyporeactivity. The "optimal" levels of parent verbal responsiveness are likely dependent on different child characteristics or dyadic qualities. More nuanced examinations of these variables are necessary to truly advance these research questions.

Conclusion

This work is a first step toward understanding the role that parent responsiveness plays in mitigating the potential negative effects of child sensory hyporeactivity on later communication outcomes. Future research should focus on child characteristics, parent characteristics, and dyadic qualities that relate to child outcomes, as a nuanced understanding of these relationships will assist in the development of tailored intervention programs for young children with or at elevated risk for ASD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

This work was supported by NICHD (T32 HD040127) and the Institute of Education Sciences, U.S. Department of Education (R324A100305 and R324B160038).

References.

Ausderau KK, Sideris J, Little LM, Furlong M, Bulluck JC, & Baranek GT (2016). Sensory subtypes and associated outcomes in children with autism spectrum disorders. Autism Research, 9(12), 1316–1327. [PubMed: 27135214]

Baranek GT (1999a). Sensory Processing Assessment for Young Children (SPA). Unpublished manuscript, University of North Carolina at Chapel Hill.

Baranek GT (1999b). Sensory Experiences Questionnaire (SEQ). Version 2.1. Unpublished manuscript, University of North Carolina at Chapel Hill.

Baranek GT, Boyd BA, Poe MD, David FJ, & Watson LR (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. American Journal on Mental Retardation, 112(4), 233–245. [PubMed: 17559291]

Baranek GT, David FJ, Poe MD, Stone WL, & Watson LR (2006). Sensory Experiences Questionnaire: discriminating sensory features in young children with autism, developmental delays, and typical development. Journal of Child Psychology and Psychiatry, 47(6), 591–601. [PubMed: 16712636]

Baranek GT, Watson LR, Boyd BA, Poe MD, David FJ, & McGuire L (2013). Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. Development and Psychopathology, 25(2), 307–320. [PubMed: 23627946]

Baranek GT, Watson LR, Crais E, & Reznick S (2003). First Year Inventory (FYI) 2.0. Chapel Hill, NC: University of North Carolina at Chapel Hill.

Baranek GT, Watson LR, Turner-Brown L, Field SH, Crais ER, Wakeford L, … & Reznick JS (2015). Preliminary efficacy of adapted responsive teaching for infants at risk of autism spectrum disorder in a community sample. Autism Research and Treatment, 2015.

Ben-Sasson A, Cermak SA, Orsmond GI, & Tager-Flusberg H (2007). Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. The American Journal of Occupational Therapy, 61(5), 584. [PubMed: 17944296]

Ben-Sasson A, Cermak SA, Orsmond GI, Tager-Flusberg H, Kadlec MB & Carter AS (2008). Sensory clusters of toddlers with autism spectrum disorders: differences in affective symptoms. The Journal of Child Psychology and Psychiatry, 49(8). 817–825. [PubMed: 18498344]

Carpenter M, Nagell K, Tomasello M, Butterworth G, & Moore C (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. Monographs of the Society for Research in Child Development, i–174.

Chow BWY, Ho CSH, Wong SW, Waye MM, & Zheng M (2017). Home environmental influences on children’s language and reading skills in a genetically sensitive design: Are socioeconomic status and home literacy environment environmental mediators and moderators? Scandinavian Journal of Psychology, 58(6), 519–529. [PubMed: 29068061]

Cycyk LM, Bitetti D, & Hammer CS (2015). Maternal depressive symptomatology, social support, and language development of bilingual preschoolers from low-income households. American Journal of Speech-Language Pathology, 24(3), 411–425. [PubMed: 25863774]

Ferjan Ramírez N, Lytle SR, Fish M, & Kuhl PK (2019). Parent coaching at 6 and 10 months improves language outcomes at 14 months: A randomized controlled trial. Developmental science, 22(3), e12762. [PubMed: 30318708]

Gotham K, Pickles A, & Lord C (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. Journal of autism and developmental disorders, 39(5), 693–705. [PubMed: 19082876]

Green J, Charman T, Pickles A, Wan MW, Elsabbagh M, Slonims V, … & Jones EJ (2015). Parent-mediated intervention versus no intervention for infants at high risk of autism: a parallel, single-blind, randomised trial. The Lancet Psychiatry, 2(2), 133–140. [PubMed: 26359749]

Haebig E, McDuffie A, & Weismer SE (2013a). The contribution of two categories of parent verbal responsiveness to later language for toddlers and preschoolers on the autism spectrum. American Journal of Speech-Language Pathology, 22(1), 57–70. [PubMed: 22878512]

Haebig E, McDuffie A, & Weismer SE (2013b). Brief report: Parent verbal responsiveness and language development in toddlers on the autism spectrum. Journal of Autism and Developmental Disorders, 43(9), 2218–2227. [PubMed: 23361917]

Hart B, & Risley TR (1995). Meaningful differences in the everyday life of America’s children. Baltimore, MD: Paul Brookes.

Hayes AF (2017). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Guilford publications.

Kasari C (2002). Assessing change in early intervention programs for children with autism. Journal of Autism and Developmental Disorders, 32(5), 447–461. [PubMed: 12463519]

Kasari C, Siller M, Huynh LN, Shih W, Swanson M, Hellemann GS, & Sugar CA (2014). Randomized controlled trial of parental responsiveness intervention for toddlers at high risk for autism. Infant Behavior and Development, 37(4), 711–721. [PubMed: 25260191]

Kinard JL, Sideris J, Watson LR, Baranek GT, Crais ER, Wakeford L, & Turner-Brown L (2017). Predictors of parent responsiveness to 1-year-olds at-risk for autism spectrum disorder. Journal of Autism and Developmental Disorders, 47(1), 172–186. [PubMed: 27785592]

Law J, Clegg J, Rush R, Roulstone S, & Peters J, T. (2019). Association of proximal elements of social disadvantage with children's language development at 2 years: an analysis of data from the Children in Focus (CiF) sample from the ALSPAC birth cohort. International Journal of Language & Communication Disorders, 54(3), 362–376. [PubMed: 30479068]

Lerner MD, White SW, & McPartland JC (2012). Mechanisms of change in psychosocial interventions for autism spectrum disorders. Dialogues in Clinical Neuroscience, 14(3), 307. [PubMed: 23226955]

Levickis P, Reilly S, Girolametto L, Ukoumunne OC, & Wake M (2018). Associations between maternal responsive linguistic input and child language performance at age 4 in a community-based sample of slow-to-talk toddlers. Child: Care, Health and Development, 44(5), 776–783.

Little LM, Freuler AC, Houser MB, Guckian L, Carbine K, David FJ, & Baranek GT (2011). Psychometric validation of the Sensory Experiences Questionnaire. American Journal of Occupational Therapy, 65(2), 207–210.

Lord C, Wagner A, Rogers S, Szatmari P, Aman M, Charman T, … & Harris S (2005). Challenges in evaluating psychosocial interventions for autistic spectrum disorders. Journal of Autism and Developmental Disorders, 35(6), 695–708. [PubMed: 16496206]

Lord C, Rutter M, DiLavore PC, Risi S, Gotham K, & Bishop SL (2012c). Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) Modules 1-4. Los Angeles, California: Western Psychological Services.

McDuffie A, & Yoder P (2010). Types of parent verbal responsiveness that predict language in young children with autism spectrum disorder. Journal of Speech, Language, and Hearing Research.

Mullen EM (1995). Mullen Scales of Early Learning. Circle Pines, MN: AGS.

Neuhauser A, Ramseier E, Schaub S, Burkhardt SC, & Lanfranchi A (2018). Mediating Rold of Maternal Sensitivity: Enhancing Language Development in At-Risk Families. Infant Mental Health Journal, 39(5), 522–536. [PubMed: 30088285]

Patten E, Ausderau KK, Watson LR, & Baranek GT (2013). Sensory response patterns in nonverbal children with ASD. Autism Research and Treatment, 2013.

Pellecchia M, Connell JE, Kerns CM, Xie M, Marcus SC, & Mandell DS (2016). Child characteristics associated with outcome for children with autism in a school-based behavioral intervention. Autism, 20(3), 321–329. [PubMed: 25911092]

Philpott-Robinson K, Lane AE, & Harpster K (2016). Sensory features of toddlers at risk for Autism Spectrum Disorder. American Journal of Occupational Therapy, 70(4), 7004220010p1–7004220010p8.

Pickles A, Harris V, Green J, Aldred C, McConachie H, Slonims V, … & PACT Consortium. (2015). Treatment mechanism in the MRC preschool autism communication trial: Implications for study design and parent-focussed therapy for children. Journal of Child Psychology and Psychiatry, 56(2), 162–170. [PubMed: 25039961]

Playford CJ, Dibben C, & Williamson L (2017). Socioeconomic disadvantage, fetal environment and child development: linked Scottish administrative records based study. International Journal for Equity in Health, 16(1), 203. [PubMed: 29166913]

Ramírez NF, Lytle SR, & Kuhl PK (2020). Parent coaching increases conversational turns and advances infant language development. Proceedings of the National Academy of Sciences, 117(7), 3484–3491.

Rogers SJ, & Ozonoff S (2005). What do we know and sensory dysfunction in autism? A critical review of the empirical evidence. Journal of Child Psychology and Psychiatry, 46(12), 1255–1268. [PubMed: 16313426]

Ryff CD, & Keyes CLM (1995). The structure of psychological well-being revisited. Journal of Personality and Social Psychology, 69(4), 719. [PubMed: 7473027]

Schreibman L, Stahmer AC, Barlett VC, & Dufek S (2009). Brief report: Toward refinement of a predictive behavioral profile for treatment outcome in children with autism. Research in Autism Spectrum Disorders, 3(1), 163–172. [PubMed: 20046210]

Siller M, Hutman T, & Sigman M (2013). A parent-mediated intervention to increase responsive parental behaviors and child communication in children with ASD: A randomized clinical trial. Journal of Autism and Developmental Disorders, 43(3), 540–555. [PubMed: 22825926]

Siller M, & Sigman M (2002). The behaviors of parents of children with autism predict the subsequent development of their children's communication. Journal of Autism and Developmental Disorders, 32(2), 77–89. [PubMed: 12058846]

Siller M, & Sigman M (2008). Modeling longitudinal change in the language abilities of children with autism: parent behaviors and child characteristics as predictors of change. Developmental psychology, 44(6), 1691. [PubMed: 18999331]

Siller M, Swanson M, Gerber A, Hutman T, & Sigman M (2014). A parent-mediated intervention that targets responsive parental behaviors increases attachment behaviors in children with ASD: Results from a randomized clinical trial. Journal of autism and developmental disorders, 44(7), 1720–1732. [PubMed: 24488157]

Sparrow SS, Cicchetti DV, & Balla DA (2005). Vineland Adaptive Behavior Scales:(Vineland II), survey interview form/caregiver rating form. Livonia, MN: Pearson Assessments.

Tamis-LeMonda CS, Bornstein MH, & Baumwell L (2001). Maternal responsiveness and children's achievement of language milestones. Child Development, 72(3), 748–767. [PubMed: 11405580]

Turner-Brown LM, Baranek GT, Reznick JS, Watson LR, & Crais ER (2013). The First Year Inventory: a longitudinal follow-up of 12-month-old to 3-year-old children. Autism, 17(5), 527–540. [PubMed: 22781058]

Venker CE, McDuffie A, Ellis Weismer S, & Abbeduto L (2012). Increasing verbal responsiveness in parents of children with autism: A pilot study. Autism, 16(6), 568–585. [PubMed: 21846665]

Vivanti G, Prior M, Williams K, & Dissanayake C (2014). Predictors of outcomes in autism early intervention: why don't we know more? Frontiers in Pediatrics, 2, 58. [PubMed: 24999470]

Warren SF, Brady N, Sterling A, Fleming K, & Marquis J (2010). Maternal responsivity predicts language development in young children with fragile X syndrome. American Journal on Intellectual and Developmental Disabilities, 115(1), 54–75. [PubMed: 20025359]

Watson LR (1998). Following the child's lead: Mothers' interactions with children with autism. Journal of Autism and Developmental Disorders, 28, 51–59. [PubMed: 9546302]

Watson LR, Crais ER, Baranek GT, Turner-Brown L, Sideris J, Wakeford L, … & Nowell SW (2017). Parent-mediated intervention for one-year-olds screened as at-risk for autism spectrum disorder: A randomized controlled trial. Journal of Autism and Developmental Disorders, 47(11), 3520–3540. [PubMed: 28861651]

Watson LR, Patten E, Baranek GT, Poe M, Boyd BA, Freuler A, & Lorenzi J (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. Journal of Speech, Language, and Hearing Research, 54(6), 1562–1576.

Whitehouse AJ, Varcin KJ, Alvares GA, Barbaro J, Bent C, Boutrus M, … & Dimov S (2019). Pre-emptive intervention versus treatment as usual for infants showing early behavioural risk signs of autism spectrum disorder: a single-blind, randomised controlled trial. The Lancet Child & Adolescent Health, 3(9), 605–615. [PubMed: 31324597]

Wolff JJ, Dimian AF, Botteron KN, Dager SR, Elison JT, Estes AM, … & IBIS Network. (2019). A longitudinal study of parent-reported sensory responsiveness in toddlers at-risk for autism. Journal of Child Psychology and Psychiatry, 60(3), 314–324. [PubMed: 30350375]

Yoder P, & McDuffie A (2006). Teaching young children with autism to talk. Seminars in Speech and Language, 27(3). 161–172. [PubMed: 16941287]

Yoder P, Watson LR, & Lambert W (2015). Value-added predictors of expressive and receptive language growth in initially nonverbal preschoolers with autism spectrum disorders. Journal of Autism and Developmental Disorders, 45(5), 1254–1270. [PubMed: 25344152]

Time 1 14 months (±0.73)	Time 2 23 months (±0.86)
Mullen Scales of Early Learning (MSEL)	Mullen Scales of Early Learning (MSEL)
Sensory Experiences Questionnaire (SEQ)	Sensory Experiences Questionnaire (SEQ)
Sensory Processing Assessment (SPA)	Sensory Processing Assessment (SPA)
Vineland Adaptive Behavior Scales (VABS)	**Vineland Adaptive Behavior Scales (VABS)**
Parent Verbal Responsiveness (PVR)[a]	**Parent Verbal Responsiveness (PVR)[a]**

Note: Bolded measures are of interest in this study. [a]An average of parent verbal responsiveness (AvgPVR) was used as a mediator variable in analyses. See text for additional details.

Figure 1.

Study Measures Gathered at Time 1 and Time 2.

Bolded measures are those of interest in this work.

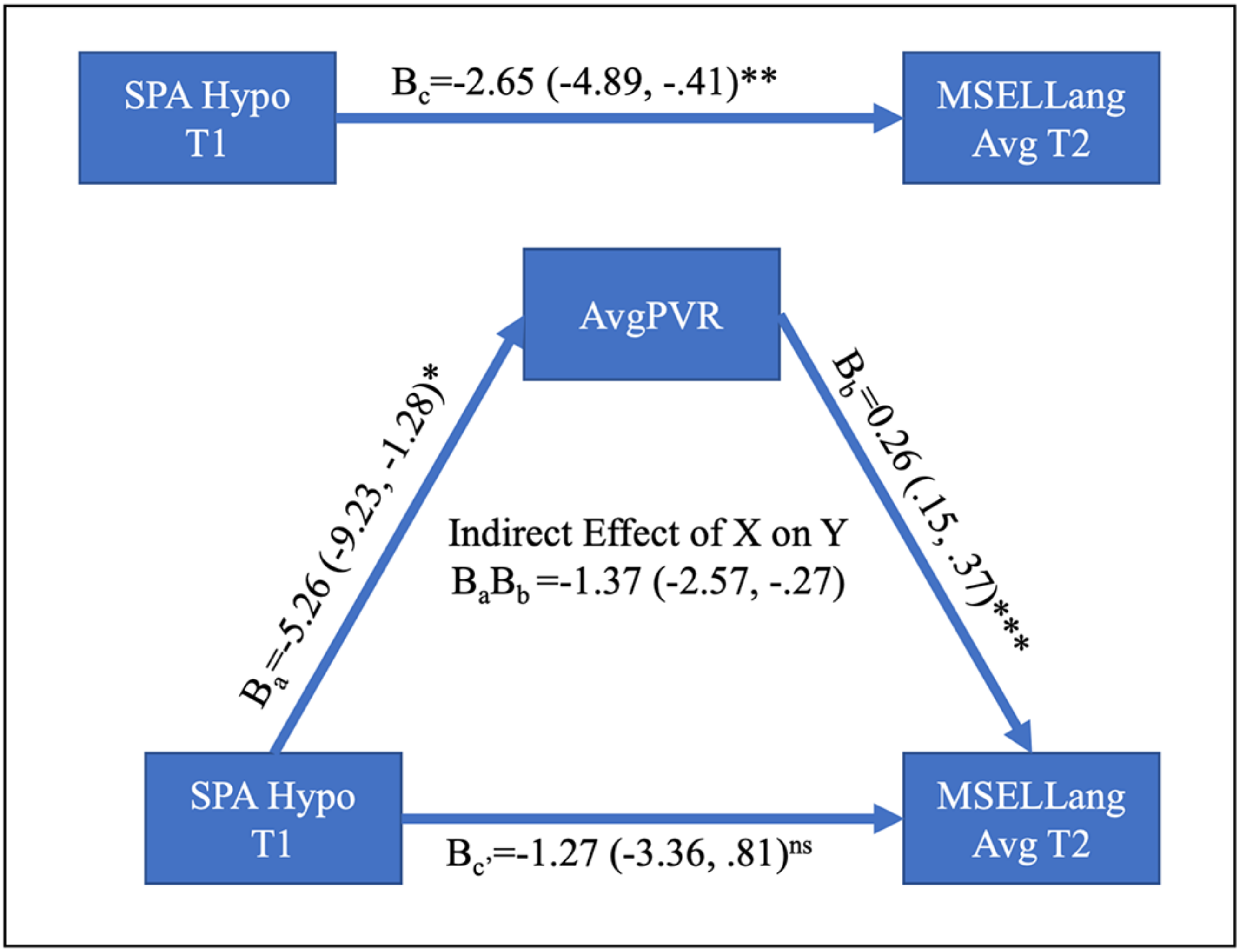

Figure 2.

SPA Mediation Analyses.

Note. Mediation analysis testing mediating effect of AvgPVR on the relationship between SPA Hypo T1 and MSEL Language Average at T2. *α<0.05 ** α<0.01 *** α<0.001; Covarying for treatment group; 10,000 bootstraps; AvgPVR= Average Parent Verbal Responsiveness; MSELLangAvg = Mullen Scales of Early Learning Average of T-scores from Expressive and Receptive Language domains at T2; SPA Hypo T1= Hyporeactivity score on Sensory Processing Assessment at Time 1.

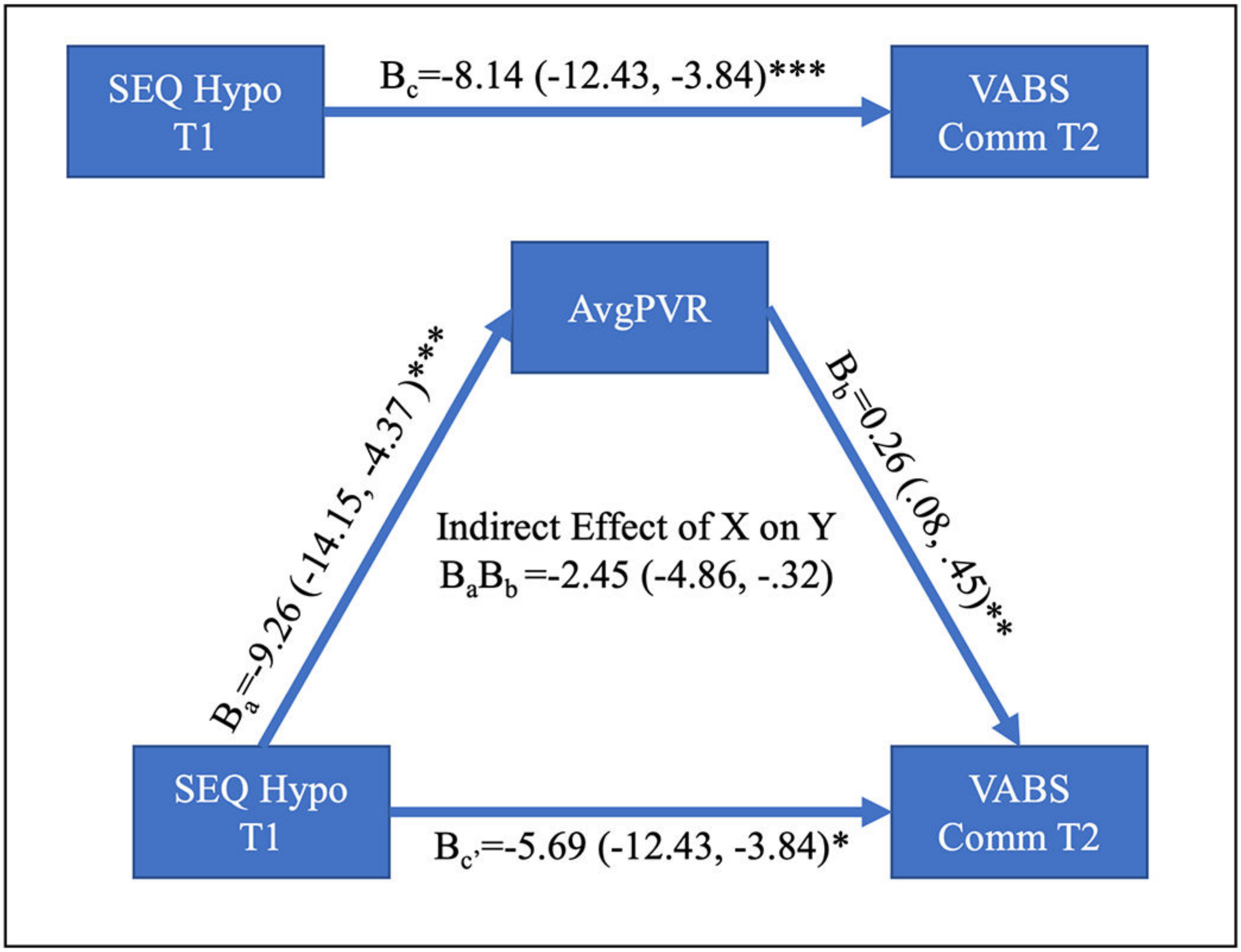

Figure 3.
SEQ Mediation Analyses.
Note. Mediation analysis testing mediating effect of AvgPVR on the relationship between SEQ Hypo T1 and VABS Comm T2. ns=not significant; *α<0.05 ** α<0.01 *** α<0.001; Covarying for treatment group; 10,000 bootstraps; AvgPVR= Average Parent Verbal Responsiveness; SEQ Hypo T1= Hyporeactivity score on Sensory Experiences Questionnaire at Time 1; VABS Comm T2= Communication Domain Standard Score of the Vineland Adaptive Behavior Scales at Time 2.

Table 1.

Background Information (n=83).

	Time 1		Time 2	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**
Age (months)	14 (0.73)	13-16	23 (0.86)	20-25
MSEL (T-Scores)				
Fine Motor	48.18 (9.51)	20-64	41.21 (12.56)	20-66
Visual Reception	45.06 (10.97)	20-76	46.23 (13.08)	20-80
Receptive Langauge	33.07 (10.96)	20-69	44.41 (16.44)	20-76
Expressive Language	34.63 (11.48)	20-65	41.27 (12.59)	20-70
ADOS				
CSS	-		4.88 (2.32)	1-10
CSS SA	-		4.31 (2.10)	1-9
CSS RRB	-		7.70 (2.10)	1-10
	n (%)			
Sex (males)	56 (67)			
Child Race[a]				
White	59 (72)			
African-American	15 (18)			
Mixed race/Other	8 (10)			
Primary Cargiver's Education Level				
Less than High School	2 (2)			
High School Diploma/GED	9 (11)			
Vocational/Associates Degree/Some College	14 (17)			
4-year College Degree	24 (29)			
Graduate/Professional Degree	34 (41)			

Note: ADOS= Autism Diagnostic Observation Schedule; CSS = Calibrated Severity Score; MSEL= Mullen Scales of Early Learning; RRB= Restricted and Repetitive Behavior; SA= Social Affect;

[a]1 parent did not report child's race.

Table 2.

Correlation between Predictor (SPA or SEQ), Outcome (MSELLangAvg or VABS Communication), and Mediator Variable (AvgPVR).

Primary Analyses.			
	1	**2**	**3**
1. SPA Hypo-Responsivity at Time 1[a]	-	−0.25*	−0.29**
2. MSELLangAvg at Time 2[b]		-	0.50**
3. AvgPVR[c]			-
Replication Analyses.			
	1	**2**	**3**
1. SEQ Hypo-Responsivity at Time 1[a]	-	−0.43**	−0.39**
2. VABS Communication at Time 2[b]		-	0.56**
3. AvgPVR[c]			-

Note:

[a]Predictor variable;

[b]Outcome variables;

[c]Mediator variable;

AvgPVR=Average Parent Responsiveness across Time 1 and Time 2; MSELLangAvg=Mullen Scales of Early Learning Average of Receptive and Expressive T Scores; SEQ=Sensory Experiences Questionnaire; SPA=Sensory Processing Assessment; VABS=Vineland Adaptive Behavior Scales.

* $\alpha<0.05$

** $\alpha<0.01$

*** $\alpha<0.001$