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Differential Associations between Sensory Response Patterns and Language, Social, and Communication Measures in Children with Autism or Other Developmental Disabilities

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Abstract

Purpose—Examine patterns of sensory responsiveness (i.e., hyperresponsiveness, hyposensitiveness, and sensory seeking) as factors that may account for variability in social-communicative symptoms of autism and variability in language, social, and communication skill development in children with autism or other developmental disabilities.

Method—Children with autistic disorder (AD; $n = 72$, mean age = 52.3 months) and other developmental disabilities (DD; $n = 44$, mean age = 48.1 months) participated in a protocol measuring sensory response patterns, social-communicative symptoms of autism, and language, social, and communication skills.

Results—Hyposensitiveness was positively associated with social-communicative symptom severity, with no significant group difference in the association. Hyperresponsiveness was not significantly associated with social-communicative symptom severity. A group difference emerged for sensory seeking and social-communicative symptom severity, with a positive association for the AD group only. For the two groups of children combined, hyposensitiveness was negatively associated with language skills and social adaptive skills. Sensory seeking also was negatively associated with language skills. These associations did not differ between the two groups.

Conclusions—Aberrant sensory processing may play an important role in the pathogenesis of autism and other developmental disabilities, as well as in the rate of acquisition of language, social, and communication skills.

Understanding the heterogeneity in children with autism is a current priority for research. The severity of social-communicative symptoms varies widely, and the course of language development also is heterogeneous, with some individuals remaining nonverbal into adulthood and others developing exceptionally advanced language skills even though pragmatic skills remain impaired. The heterogeneity in both severity of social-communicative symptoms and the development of language and adaptive social and communication skills has important prognostic implications (Charman, Taylor, Drew, Cockerill, Brown & Baird, 2005; Luyster, Qiu, Lopez, & Lord, 2007; Szatmari, Bryson, Boyle, Streiner, & Duku, 2003; Venter, Lord, & Schopler, 1992). A long-term goal of our program of research is to understand the associations between sensory patterns and the core symptoms of autism, as well as between sensory patterns and language, social, and

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communication skill development. Thus, although the current study is a correlational study of concurrent measures on young children with autism and other developmental disabilities (DD), the implications of the findings for a developmental model are of particular interest.

Developmental Framework for Possible Links between Sensory Responses and Social, Communication, and Language Functioning in Children with Autism

Any plausible hypothesis about processes underlying the phenotypic expressions of autism needs to consider a developmental perspective (Bailey, Phillips, & Rutter, 1996). Impairments in one developing system may have secondary consequences for later-developing systems. Thus, research establishing linkages between individual differences in basic sensory processing and social, communication, and language functioning of children with autism could have implications for developmental models accounting for heterogeneity in this population.

Although we know little about the early trajectories of responsiveness to sensory stimuli in children with autism specifically, research related to constructs of selective attention in other populations of infants can shed light on these issues. Two behavioral responses to sensory stimuli, orienting and defensiveness, have been used as measures of efficiency of sensory processing, and these provide a window to understanding selective attention. In infancy, orienting and defensive responses occur in the pre-attentive stages of processing and are thought to reflect functionally different modes of information processing (Lang, Simons, & Balaban, 1997). Orienting responses occur when a sensory event captures a child's attention, and are important for enabling further exploration of the environment. However, if the stimulus is intense, defensiveness or startle is expected. Problems in orienting and defensive responses (e.g., tactile and movement hypersensitivities) in infancy are associated with an increased risk for developmental delays and social-emotional problems at three years of age (DeGangi, Breinbauer, Roosevelt, Porges, & Greenspan, 2000), emphasizing the foundational nature of these processes.

We assume that sensory processing patterns also lay developmental foundations for social, communication, and language functioning in infants later diagnosed with autism. Any type of disruption in typical sensory response patterns arguably may contribute to later difficulties. For example, although orienting to sensory stimuli per se would not sufficient to ensure the social motivation and skills for appropriate, reciprocal social-communicative interactions, failing to orient to stimuli would preclude further engagement in social-communicative interactions that might occur following the capture of attention. Thus, we would expect that children with more extreme problems in orienting will have more severe social-communicative symptoms. Poor orienting and defensive reactions may be associated with extreme states of physiological arousal, which have been linked to decreased perceptual and contingency learning in bobwhite quail neonates (Markham, Toth & Likliter, 2006) and premature human infants (Haley, Grunau, Oberlander, & Weinberg, 2008), respectively.

The present study examines associations between sensory processing patterns and social, communication, and language functioning of young children with autism compared to children with other DD as an initial step in the evolution of a developmental model to account for (a) variable phenotypic expressions of social-communicative symptoms used to make a diagnosis of autism, and (b) variable outcomes in language skill level and social and communication adaptive functioning, compared to developmental norms. Testing such a developmental model could not only yield theoretical implications, but practical applications in terms of identifying the need to address sensory response patterns in intervention.

Sensory Response Patterns in Children with Autism

Previous research has demonstrated that children with autism demonstrate unusual responses to sensory stimuli to a greater degree than their peers with other DD or typical development (Baranek, David, Poe, Stone, & Watson, 2006; Lord, Rutter, & LeCouteur, 1994; Rogers, Hepburn, & Wehner, 2003; Wiggins, Robins, Bakeman, & Adamson, 2009). Although these unusual behaviors have been categorized in different ways, one current empirically-supported conceptualization focuses on response patterns of hyporesponsiveness, hyperresponsiveness, and sensory seeking as three separable sensory processing constructs (Ashburner, Ziviani, & Rodger, 2008; Ben-Sasson, Cermak, Orsmond, Tager-Flusberg, Kadlec, & Carter, 2008; Boyd et al., 2010; Liss, Saulnier, Fein, & Kinsbourne, 2006). Hyporesponsiveness is characterized by an absence of the expected response to a stimulus (e.g., failing to orient to a novel sound in the environment), a delayed response, or a higher response threshold (e.g., only orienting to a novel sound when it becomes more intense). Hyperresponsiveness is characterized by an exaggerated behavioral reaction, aversive response, or effort to avoid a sensory stimulus. Sensory seeking behaviors are actions that perpetuate or intensify a sensory experience, such as staring intensely at flickering lights or sniffing objects. These patterns are not mutually exclusive and may co-occur in individual children across sensory modalities (Baranek et al., 2006; Liss et al., 2006).

Around the end of the first year of life, behavioral features that include sensory symptoms differentiate infants who will later be diagnosed with autism from infants with other DD or with typical development. Specifically, Baranek (1999a) found that infants later diagnosed with autism (a) required more prompts before responding to a name call and were less likely to orient to visual stimuli introduced into the environment than children with other DD, perhaps showing the early emergence of a hyporesponsive pattern; (b) were more likely to show aversive responses to social touch, perhaps symptomatic of an emerging hyperresponsive pattern; and (c) engaged in more mouthing of objects, perhaps an early symptom of a sensory seeking pattern. Importantly, these sensory symptoms were apparent prior to the time that most parents had any concerns about their infants later diagnosed with autism. The early appearance of distinctive sensory symptoms in infants with autism is consistent with our model, which proposes that aberrations in early developing sensory processing systems may lead to consequences in other developmental domains.

Looking at sensory patterns beyond the infancy period, children with autism demonstrate more extreme hyporesponsiveness than children with other DD (Baranek et al., 2006; Miller, Reisman, McIntosh, & Simon, 2001; Rogers & Ozonoff, 2005). Although children with autism may not be generally more hyperresponsive than those with other DD (Baranek et al., 2006; also see review by Rogers & Ozonoff, 2005), they are more likely to demonstrate co-occurring hyporesponsiveness and hyperresponsiveness than children with other DD (Baranek et al., 2006).

Compared to hyporesponsiveness and hyperresponsiveness, limited research has focused on sensory seeking in different populations. In addition, no consensus has emerged on the relationships between sensory seeking and hyporesponsiveness or hyperresponsiveness, although sensory seeking often has been conceptualized and measured as an aspect of hyporesponsiveness. The underlying assumption for merging the two response patterns is that sensory seeking represents a compensatory strategy used by an individual with a high threshold for registering sensory stimuli (Dunn, 1997). However, hyporesponsiveness and sensory seeking are distinguished behaviorally from one another in that hyporesponsiveness is associated with the appearance of passivity and disengagement, in contrast with the active engagement and frequently positive affect associated with sensory seeking. Two alternate conceptualizations are that sensory seeking may be a soothing mechanism when an

individual is over-aroused (Liss et al., 2006), or a modulatory mechanism for both over- and under-arousal (Baranek, Reinhartsen, & Wannamaker, 2001).

Another issue related to sensory responsiveness among children with autism is whether extreme sensory responses are differentially associated with social and nonsocial stimuli. In a seminal study, Wing and Gould (1979) reported that children who were indifferent to social stimuli (i.e., nonresponsive) had a high likelihood of also being nonverbal. These investigators did not examine the possibility that indifference to social stimuli is part of a broader pattern of hyporesponsiveness, but subsequent research has indicated that hyporesponsiveness in autism is not limited to social stimuli alone. Rather, children with autism show unusual sensory responses to both social and nonsocial stimuli, with the patterns more pronounced with social stimuli (Baranek, 1999a; Baranek et al., 2006; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998).

Association between Sensory Response Patterns and Social-Communicative Symptoms of Autism

Most research on sensory patterns among individuals with autism has focused on between-group comparisons of sensory symptom severity in individuals with autism to those with typical development or other DD. It remains unclear whether various sensory patterns are differentially associated with social-communicative symptoms of autism. For the current purposes, social-communicative symptom severity refers to the extent to which an individual manifests those core symptoms of autism as described in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision; DSM-IV-TR; APA, 2000) and as quantified by assessment tools using DSM-IV/DSM-IV-TR as a reference point for determining validity.

Although several investigations have reported that the overall severity of sensory symptoms is positively associated with autism symptom severity (Adamson, O'Hare, & Graham, 2006; Ben-Sasson et al., 2008; Kern et al., 2007), few studies have analyzed the *differential* association of sensory response patterns (such as hyporesponsiveness, hyperresponsiveness, and sensory seeking) with different core autism symptoms (i.e., social, communicative, and restricted/repetitive behaviors and interests). The available studies have used parent questionnaires to measure both sensory constructs and symptom severity. Liss et al. (2006) found that hyporesponsiveness and sensory seeking correlated positively with both social and communication symptom severity among children and adults with autism spectrum disorders. Further, hyperresponsiveness correlated with social symptoms, but not with communication symptoms. Hilton, Graver and LaVesser (2007) studied elementary school-age children with high-functioning autism spectrum disorders and found that sensory seeking, low registration (hyporesponsiveness), and sensory avoiding/sensory sensitivity (hyperresponsiveness) were all related to social-communicative symptom severity.

Associations between Sensory Response Patterns and Language, Social, and Communication Skills

For the purposes of this investigation, language, social, and communication skills are defined as those indexed by standardized measures developed for the general population, without specific reference to symptoms associated with autism. Development of such skills is at least partially separable from social-communicative symptom severity in autism. That is, individuals without autism may show marked delays in acquiring expected language, social, and communication skills, and, conversely, individuals with autism may show some age-appropriate developmental and adaptive skills in aspects of language, social, and communication functioning. Klin and colleagues (2007) demonstrated within a sample of high functioning individuals with autism (VIQ>70) that only a weak association existed

between social-communicative symptoms of autism and adaptive social or communication skills, supporting the claim that measures of developmental skills are not completely redundant with measures of autism symptom severity.

Similar to the situation with social-communicative symptoms of autism, few studies have examined the differential association of sensory response patterns to social and communication skills. In one such study, Liss and colleagues (2006) found only weak associations with social and communication adaptive behavior in 144 children and adults with autism spectrum diagnoses. Specifically, hyperresponsiveness was negatively related to social adaptive skills ($r = -.20$) and sensory seeking was negatively related to communication adaptive skills ($r = -.24$). Taking a different analytical approach, Lane and colleagues (Lane, Young, Baker & Angley, 2010) found that the domains of Underresponsiveness/Seeks Sensation and Low Energy/Weak from the Short Sensory Profile (Dunn, 1999) each accounted for unique variance in communication adaptive skills in children with autism spectrum disorders, but did not find that sensory measures accounted for significant variance in social adaptive skills.

Rationale for the Current Study

Overall, the limited existing research suggests that different sensory patterns have varying associations with social-communicative symptoms of autism, and with social and communication adaptive skills. Associations of sensory response patterns with language skills per se have not been examined. Further understanding of these differential associations could contribute to the evolution of a developmental model linking sensory processing with social, communication, and language functioning in children with autism.

Our specific research questions are as follows:

1. For children with autism and those with other DD:
 - a. *To what extent are different sensory response patterns (hyperresponsiveness, hyporesponsiveness, and sensory seeking) associated with the severity of social-communicative symptoms of autism?*
We hypothesized that children with more extreme hyporesponsiveness would demonstrate more social-communicative symptoms of autism (e.g., unusual eye contact, lack of social responses, failure to show objects to others). Based on findings that elevated hyporesponsiveness is the sensory pattern that most distinguishes children with autism from those with other DD, we expected to find that this prevalent pattern of sensory responsiveness is most strongly associated with the social-communicative symptoms of autism. We also hypothesized that the sensory patterns of hyperresponsiveness and sensory seeking would have a positive relationship to severity of social-communicative symptoms, given the prevalence of these sensory patterns among children with autism. However, because hyperresponsiveness is less specific to children with autism, we anticipated its association with social-communicative symptoms of autism would be weaker than for hyporesponsiveness. Previous empirical literature does not clarify the extent to which sensory seeking is specific to children with autism.
 - b. *Are the associations between sensory response patterns and severity of social-communicative symptoms of autism the same for both groups of children?* Our conceptual framework did not lead to any hypotheses that the direction and magnitude of these associations would differ based on

diagnostic group, so this was an exploratory question to inform future refinement of a developmental model.

2. For children with autism and those with other DD:

- a. *To what extent are different sensory response patterns associated with language, social, and communication skills?* We hypothesized that the sensory pattern of hyporesponsiveness would negatively correlate with children's language skills as well as their social and communication adaptive skills. This hypothesis was based first on a theoretical assumption in our model that orienting to sensory stimuli is essential for subsequent learning from stimuli; thus, the more hyporesponsive a child is, the more restricted his or her language, social, and communication learning opportunities will be. We also hypothesized that patterns of hyperresponsiveness and sensory seeking would negatively correlate with language skills and social and communication adaptive skills, based on theoretical assumptions that overly intense sensory response patterns reflect arousal modulation difficulties that disrupt learning processes.
- b. *Are the associations between sensory response patterns and language, social, and communication skills the same for both groups of children?* As above, our conceptual framework did not lead to any hypotheses regarding this question, but findings could inform a developmental model. Children with autism and those with other DD overlap considerably on their scores on measures of language skills and social and communication adaptive skills. Thus, a developmental model to account for associations between these skills and sensory patterns in autism needs to consider that children with other DD also can exhibit significant delays in developing these skills despite the fact that, in general, their patterns of sensory responsiveness are more comparable to those observed in typically developing children.

Method

Participants

Recruitment—Two groups of participants were included in this study: children with autistic disorder (AD) ($n = 72$) and children with other DD ($n = 44$). See Table 1 for a summary of participant and family descriptive and demographic information. The families received monetary incentives (\$25 – \$75 dependent upon their child's age and diagnostic status) for their participation in the study. The children also received a small toy or book for their contributions. Recruitment strategies included: seeking referrals from a university-based research subject registry; distributing brochures to developmental clinics, parent support groups, and local public schools; staffing information booths at conferences attended by families of children with autism or other special needs; sending out information electronically through listservs; and maintaining a project website. Prior to assessments, research staff screened children to confirm normal or corrected normal vision and hearing, as atypical hearing or vision could impact sensory processing and subsequent reactions. The university's Institutional Review Board approved the research, and a parent of each child signed an informed consent for the child's participation.

Diagnostic confirmation—The AD group was comprised of children diagnosed with autism by an independent licensed psychologist or physician. Research staff confirmed the diagnosis with the *Autism Diagnostic Interview-Revised* (ADI-R; LeCouteur, Lord, & Rutter, 2003) and *Autism Diagnostic Observation Schedules* (ADOS; Lord et al, 1999). These two instruments were developed to promote more consistency in diagnostic

assessments of individuals to evaluate whether their symptoms are consistent with a diagnosis of AD. Children had to meet criteria for AD on both instruments to be included in the AD group. The ADI-R is a caregiver interview; it provides a diagnostic algorithm based on lifetime history of symptoms as well as an algorithm score for current symptoms. The ADOS is a semi-structured direct assessment including a series of “presses” to provide opportunities to elicit and observe autism symptoms. The revised algorithm scores (Gotham et al., 2007) used in this study provide subdomain scores for social-communicative symptoms and repetitive and stereotyped behavior symptoms. Research staff administering these measures obtained research-appropriate levels of reliability with a University of Michigan Autism and Communication Center-certified examiner, and reliability of scoring was checked by the certified examiner on a minimum of 20% of assessments throughout the study.

The DD group included three types of children: (a) those with known genetic syndromes (i.e., Down or Williams syndrome) associated with intellectual disability ($N = 20$); (b) those with idiopathic developmental delay of a nonspecific nature ($N = 19$), based on either a global cognitive assessment (i.e., IQ >2 standard deviations below the mean), or significant delays (>1.5 standard deviations below the mean) in at least two developmental domains (i.e., Expressive Language, Receptive Language, Cognitive/Visual Reception, Fine or Gross Motor, and/or Adaptive Behavior); or (c) developmental delay associated with premature birth ($N = 5$). The recruitment of some children for the DD group with milder developmental delays was intentional, due to the inclusion of children with a wide variety of cognitive levels (from severely delayed to above average) in the AD group. We excluded children from the DD group if they had a clinical diagnosis of an autism spectrum disorder or met research criteria for autism on the ADOS and/or the *Childhood Autism Rating Scale* (CARS; Schopler, Reichler, & Renner, 1988). An exception was made for children with mental ages of less than 18 months, because the ADOS is not standardized for children at low mental ages, and the ADOS-Toddler version was not available at the time of this study. Thus, for five children with low mental ages in the DD group, clinical impressions and results from other autism diagnostic assessments overrode ADOS results. The ADI-R was not administered to children in the DD group unless they met criteria for autism on the ADOS and further clarification of diagnostic status was sought for that reason.

Exclusion criteria for both groups (AD and DD) were: the presence of co-morbid conditions of autism, such as fragile X syndrome and tuberous sclerosis; mental age (MA) < 6 months; cerebral palsy; uncorrected vision or hearing impairment; seizure disorder; or current receipt of psychopharmacological treatments as indicated by parents or from medical records. Children receiving psychopharmacological treatments were excluded because it is unknown to what degree medications such as stimulants and psychotropics may alter sensory responsiveness.

Measures Used in Analyses

Nonverbal cognitive measures—The Visual Reception (VR) scale of the *Mullen Scales of Early Learning* (MSEL; Mullen, 1995) was used as a nonverbal cognitive measure for the majority of participants. The MSEL is a standardized, examiner-administered measure of cognitive functioning for children from birth up to 68 months of age. The VR scale primarily tests visual discrimination and visual memory skills, and was selected as an efficient and valid measure of nonverbal cognitive performance. We utilized the VR age equivalent scores as an estimate of nonverbal MA. Some participants (13%) were above the age range recommended for the MSEL; in those cases, the Brief IQ of the *Leiter International Performance Scale-Revised* (Roid & Miller, 1997), another measure of nonverbal cognitive skills, was substituted and an age equivalent derived. Nonverbal MA

was chosen as a covariate for our analyses for two reasons: (a) it is conceptually separate from the language skills of interest as one of our outcome measures; and (b) previous research from our laboratory has demonstrated that sensory symptoms are negatively related to MA (more strongly than to CA or IQ) (Baranek et al., 2006; Baranek, Boyd, Poe, David & Watson, 2007).

Social-communicative symptom severity measure—Based on recent evidence that social and communication symptoms of autism aggregate into a single factor (e.g., Frazier, Youngstrom, Kubu, Sinclair, & Rezai, 2008; Georgiades et al., 2007; Gotham, Risi, Pickles, & Lord, 2007; Snow, Lecavalier, & Houts, 2009), we chose to examine the association of sensory patterns to social-communicative symptoms combined. A measure of social-communicative symptom severity was derived from the ADOS. The ADOS social-communicative algorithm scores came from ADOS Modules 1, 2, and 3, respectively, for different children. Because more children were assessed with Module 1, scores on the other modules were scaled to the range of possible algorithm scores for Module 1.

Language measures—Children's language skills were measured with two different instruments that measure similar abilities: the MSEL (see above) Receptive Language (RL) and Expressive Language (EL) scales, and the *Preschool Language Scale-4th edition* (PLS-4; Zimmerman, Steiner & Pond, 2002). The PLS-4 is a standardized language test with two subscales: Auditory Comprehension (AC) and Expressive Communication (EC). It is designed for use with children from birth through 6 years, 11 months. We aggregated these similar measures to produce a smaller number of variables for analysis and to reduce measurement error introduced by chance fluctuations in performance on a single measure of a skill domain (see Thorndike, 2005). A mean receptive language quotient score (RLQ) was calculated from the MSEL RL and the PLS-4 AC subscales (i.e., by averaging the language age equivalent scores from the two subscales and then dividing by the chronological age), and a mean expressive language quotient (ELQ) was similarly calculated from the MSEL EL and the PLS-4 EC subscales. Each score was then multiplied by 100 to yield a language quotient score. As will be explained, the RLQ and ELQ were combined into a single language quotient (LangQ) for the final analyses. Standard scores were not used due to the large number of children obtaining the lowest possible standard scores on the language measures, thereby truncating the variability.

Social and communication adaptive skills measure—The *Vineland Adaptive Behavior Scales-Survey Edition* (VABS; Sparrow, Balla, & Cicchetti, 1984), a structured, standardized caregiver interview, was administered to a parent of each participant. The VABS includes communication, socialization, daily living, and motor skills scales. For the purposes of the present study, we used standard scores for the communication and socialization scales. Because the VABS provides a larger range of standard scores than are available for the language measures described above, it was not necessary to calculate ratio scores to avoid floor effects in analyses involving the VABS scale scores.

Sensory measures—A total of four sensory measures were used -- two parent report and two observational -- providing a multi-trait, multi-method approach to measuring the three sensory constructs of interest. This approach, combining multiple assessments across different measurement formats, has been recommended in the measurement of psychological constructs (Eid, Nussbeck, Geiser, Cole, Gollwitzer, & Lischetzke, 2008; John & Benet-Martinez, 2000).

The *Sensory Experiences Questionnaire* (SEQ; Baranek, 1999b; Baranek et al., 2006) is a caregiver questionnaire (Likert 5-point scale) with 43 items measuring frequencies of the child's unusual sensory reactions across sensory modalities (e.g., visual, tactile, auditory),

contexts and response patterns (i.e., hyporesponsiveness, hyperresponsiveness, and sensory seeking). The SEQ was developed for children with autism or other developmental delays ages 6 months through 12 years. The overall internal consistency (reliability) of the SEQ is .80 (Cronbach's alpha) and the test-retest reliability is .92 (intraclass correlation coefficient) (Little et al., in press); in addition, the SEQ was found to discriminate autism from developmental delay and typical development in a known-groups validity study (Baranek et al., 2006).

The *Sensory Profile* (SP; Dunn, 1999) is a 125-item questionnaire (Likert 5-point scale) that also measures sensory processing across modalities in the context of daily activities. This standardized assessment is used to measure severity of sensory processing problems across clinical populations, including children with autism (Kientz & Dunn, 1997).

The *Sensory Processing Assessment for Young Children* (SPA; Baranek, 1999c) is a 20-minute, semi-structured, play-based assessment that provides behavioral presses for different sensory response patterns in children ages 9 months to 6 years. Designed to assess children with autism and other DD, the SPA enables observation of child responses to stimulation of the tactile, auditory and visual modalities through interaction with novel sensory toys and unexpected stimuli. Intraclass correlation coefficients (agreement for two raters across items in each scale for a subsample of 34 children) were .87 for aversion (tapping hyperresponsiveness) and .90 for habituation (tapping hyporesponsiveness), indicating good reliability.

The *Tactile Defensiveness and Discrimination Test- Revised* (TDDT-R; Baranek, 1998; Baranek & Berkson, 1994) is a 15-minute behavioral assessment of tactile processing (hyperresponsiveness and discrimination) for preschool and school-aged children with autism and other DD. Levels of tactile defensiveness based upon this assessment reliably discriminated 34 children with various developmental disabilities including autism (Baranek & Berkson).

Derivation of Sensory Construct Scores

To measure the triad of sensory patterns, items from each of the four sensory measures (i.e., SEQ, SP, SPA, and TDDT-R) were grouped into one of the three sensory constructs of interest (hyporesponsiveness [HYPO], hyperresponsiveness [HYPER] and sensory seeking [SEEKING]). The SEQ contributed 33 items (HYPO [6], HYPER [14], SEEKING [13]); the SP contributed a total of 64 items (HYPO [10], HYPER [29], SEEKING [25]); the TDDT-R contributed 39 items (HYPO [1], HYPER [31], SEEKING [7]), and the SPA contributed 31 items (HYPO [7], HYPER [17], SEEKING [7]). Scoring valences and ranges for all items were adjusted for compatibility, such that all were scaled to fit a 5-point scale, and higher scores indicated more sensory symptoms across all measures.

Using a factor analytic model, we created factor scores for HYPO, HYPER and SEEKING, adjusting for reporter biases. To do this, we created a measurement model in MPLUS (Muthén & Muthén, 2005) that had five latent constructs (HYPO, HYPER, and SEEKING, "Observed," and "Parent Report") and 11 manifest variables (Figure 1). Three of the sensory instruments contained sufficient HYPO, HYPER, and SEEKING items to provide a manifest variable for each sensory pattern, whereas the TDDT-R had insufficient items to contribute a manifest variable for the HYPO pattern. To correct for rater effect, latent variables representing parent report effects (the SEQ and SP) and direct observational measure effects (the SPA and TDDT-R) were also included in the model. The measurement model had good fit, as shown by a non-significant chi-square ($\chi^2 = 32.4$; $p = .40$), a CFI near 1 (CFI = 0.997), and a RMSEA < .08 (RMSEA = 0.021). To simplify score interpretation, the resulting factor

scores were standardized so that each sensory construct had a mean of 0 and a standard deviation of 1.

Statistical Analysis

Once the factor analytic model was fit to the sensory data, the standardized factor scores for each child were used in a mixed model framework to assess the associations of the three sensory response patterns with (a) severity of social-communicative symptoms of autism, (b) language scores, and (c) social adaptive scores, and (d) communication adaptive scores. We covaried for nonverbal MA in all analyses due to evidence that sensory symptoms are inversely related to MA (Baranek et al., 2006; 2007), and also covaried for gender due to the significant disparity in the proportion of males in the AD group compared to the DD group (see Table 1).

Results

The means and standard deviations for the sensory construct scores, severity of social-communicative symptoms, receptive and expressive language quotient scores and total language quotient score, and social and communication adaptive standard scores are provided in Table 2. Prior to analyses to address our research questions, we compared the scores of children in the AD and DD groups on the three sensory constructs, covarying for nonverbal MA and gender. The adjusted sensory construct scores are given in Table 3, which also shows the results indicating that HYPO, HYPER, and SEEKING scores were all significantly higher in the AD group than in the DD group. In addition, the groups were significantly different on ADOS algorithm scores ($AD > DD$, $p < .001$), language quotient scores ($AD < DD$, $p = .027$), and Vineland Social scores ($AD < DD$, $p < .001$), but not on Vineland Communication scores ($p = .500$).

Research Question 1: For children with autism and those with other DD: (a) To what extent are different sensory response patterns associated with severity of social-communicative symptoms? (b) Are the associations between sensory response patterns and severity of social-communicative symptoms of autism the same within both groups of children?

For this question, we examined the extent to which different sensory constructs were associated with social-communicative symptoms of autism as measured by the ADOS algorithm scores. The results are shown in Table 4. The HYPER pattern showed a nonsignificant association with severity of social-communicative symptoms of autism, and the association did not differ as a function of group. The HYPO pattern showed a significant positive association with social-communicative symptom severity ($\beta = .05$; $SE = .02$). Given the range of the ADOS scores (Table 2), a β of this magnitude would result in a HYPO score difference of .7 standard deviations between those with the highest and lowest ADOS scores. This association did not differ as a function of group. The AD and DD groups differed significantly from each other in how SEEKING related to social-communicative symptom severity ($p = .010$). Thus, the results for the AD and DD groups were examined separately, and showed a significant positive association between SEEKING and social-communicative symptom severity for the AD group ($\beta = .08$; $SE = .03$), but a nonsignificant negative association for the DD group. Given the range of the ADOS scores of the AD group, this magnitude of β would result in a SEEKING score difference of 1.1 standard deviations between those with the highest and lowest ADOS scores.

Research Question 2: For children with autism and those with other DD: (a) To what extent are different sensory response patterns associated with language, social and

communicative skills? (b) Are the associations between sensory response patterns and language, social and communication adaptive skills the same for both groups of children?

First, we examined the association between sensory patterns and language scores. We initially fit separate models for RLQ and ELQ. Due to highly similar results for these two models, as well as strong intercorrelations among the four language scores ($\geq .90$ within the AD group; $\geq .70$ within the DD group, and $\geq .87$ for the two groups combined), we report results only for total LangQ. As shown in Table 5, HYPO and SEEKING were negatively related to language skills (i.e., fewer sensory symptoms in these areas were associated with higher LangQ), whereas HYPER was not significantly associated with language skills. No group differences were found in the direction or magnitude of associations. Given the range of the language scores (Table 2), this would result in a HYPO score difference of 1 standard deviation between those with the highest and lowest language scores, and a SEEKING score difference of 1.2 standard deviations between those with the highest and lowest language scores.

We then fit models to examine the association between the VABS Social and the VABS Communication subscale scores. HYPO was significantly negatively related to social adaptive scores ($\beta = .02$; $SE = .01$). Given the range of the VABS Social scores (Table 2), this would result in a HYPO score difference of 1 SD between those with the highest and lowest VABS scores. No other associations between social or communication adaptive skills reached significance, although the associations of HYPO ($p = .052$) and SEEKING ($p = .090$) with communication adaptive scores showed trends that were consistent with the findings in the previous analysis for the associations of these sensory patterns with language skills. Again, no group differences were found in the direction or magnitude of associations in these latter two models (see Table 5).

Discussion

Sensory Response Patterns and Severity of Social-Communicative Symptoms of Autism

Our findings related to the patterns of associations between sensory symptoms and the severity of social-communicative symptoms of autism partially supported our hypotheses. As predicted, hyporesponsiveness had a significant positive association with social-communicative symptom severity. The lack of group differences in the magnitude or direction of association between hyporesponsiveness and social-communicative symptom severity suggests that the differences between the two groups in these domains may be confined to a difference in the degree to which children are hyporesponsive (children with AD are more hyporesponsive) and in the severity of social-communicative symptoms of autism (children with AD are more severe). This interpretation is consistent with the findings of Dawson et al. (1998), who reported that orienting to social stimuli was concurrently associated with shared attention both in children with autism and in children with Down syndrome

Contrary to our hypothesis, hyperresponsiveness was not significantly positively associated with social-communicative symptom severity. In fact, there was a nonsignificant trend toward a negative association between hyperresponsiveness and social-communicative symptoms, opposite of the direction of effects for hyporesponsiveness. The contrast between findings for hyperresponsiveness and hyporesponsiveness possibly can be explained by differing opportunities to activate compensatory strategies associated with these two sensory response patterns. Hypothetically, a child who is under-reactive to many stimuli may have an attention system that often fails to perceive exogenous stimulus features as salient. If there is a breakdown in exogenously-controlled attention processes, the child would have no opportunity to activate more cognitively-based, endogenous compensatory strategies that

potentially could mediate the association between sensory response and expression of social-communicative symptoms of autism. In the case of hyperresponsiveness, the opportunity to activate compensatory strategies following the capture of attention would be present, although children would differ in the extent to which they have the cognitive capacities to do so. Potential mediating variables such as these could be explored in future studies to unravel mechanisms underlying these differential associations of sensory response patterns to social-communicative symptom severity.

Our findings for an association between sensory seeking and symptom severity were more complex in that this was the single analysis in which the association between a sensory construct and an outcome variable differed by group. In fact, the association for children with autism was significantly positive (with a similar effect magnitude as for hyporesponsiveness), whereas it showed a negative trend for children with other DD. These results imply potential differences in processes or mechanisms associated with sensory seeking behaviors in these two groups. Possibly behaviors scored as sensory seeking in the DD group reflected immature strategies for exploring the environment that were not otherwise unusual (such as excessive mouthing of objects persisting in a preschooler). Among children with autism, however, sensory seeking behaviors appeared to include both behaviors that looked immature but not otherwise unusual, as well as behaviors that looked unusual compared to behaviors seen in typically developing children (such as turning flat objects to sight down the edge of the object). Children with autism have documented difficulty in disengagement and shifting of attention, compared to children with typical development or other DD (Landry & Bryson, 2004; Zwaigenbaum et al., 2005). We question whether sensory seeking behaviors among children with autism are related to problems with attention disengagement, such that children with autism are less able to respond to social stimuli when their attention is already engaged by nonsocial stimuli. If the types of sensory seeking behaviors observed among children with other DD do not reflect problems with disengaging and shifting attention to respond to social stimuli, then this may be an explanation for the lack of significant association between sensory seeking and severity of social-communicative symptoms within this group. The construct of sensory seeking warrants additional research within and across populations of children with autism and other DD.

The above findings contrast in several respects with the limited previous research on this topic, and warrant careful consideration. Liss et al. (2006) found significant positive correlations of social symptom severity with all three sensory constructs, and significant positive correlations of communication symptom severity with hyporesponsiveness and sensory seeking. Similarly, Hilton et al. (2007) found positive correlations between social-communication symptom severity and all three sensory constructs. Thus, our study converges with these previous studies related to the associations of hyporesponsiveness and sensory seeking with social-communication symptoms of autism, but diverges regarding hyperresponsiveness. Neither of these studies covaried for MA; comparing their results to ours, in which MA was covaried, suggests that the association between hyperresponsiveness and social symptom severity may be mediated to some extent by cognitive abilities. In addition, the previous studies measured sensory features only via parent report data from a single instrument, which may result in less reliable measurement of the sensory constructs of interest than the measurement model employed in the current study.

Although recent theories of enhanced sensory perception relate sensory hypersensitivities to hypersystemizing abilities in individuals with autism (Baron-Cohen, Ashwin, Ashwin, Tavassoli & Chakrabarti, 2009; O'Riordan & Passetti, 2006), our findings indicate that patterns of hyporesponsiveness and seeking, but not hyperresponsiveness, are linked to the severity of the core social-communicative symptoms of autism. These findings point to a

need for more research examining the roles of each of these sensory patterns in the pathogenesis of autism.

Sensory Response Patterns and Language, Social and Communication Skills

The results of the current investigation supported our hypothesis that hyporesponsiveness would be negatively associated with language quotient scores as well as social adaptive scores. This finding is consistent with the assumptions of our developmental model, which posits that registering and orienting to salient stimuli in the environment is an important developmental prerequisite for learning language, social, and communication skills.

Our results pertaining to hyporesponsiveness and social adaptive skills run counter to those of Liss et al. (2006) and Lane et al. (2010), who did not find evidence supporting relationships between these variables in their groups of individuals with autism spectrum disorders. Several methodological differences between those studies and the current study may account for the discrepancies: (a) both of these previous studies examined somewhat older children with autism spectrum disorders; (b) both measured sensory symptoms via a parent report alone; and (c) neither covaried for nonverbal mental age, as was done in the current study.

Hyperresponsiveness was not significantly associated with language quotient scores or with social or communication adaptive scores. This finding ran counter to our assumption that unusual sensory response patterns of any type would disrupt learning processes, and thus be negatively associated with scores on these measures. Although a failure to find a significant concurrent association does not necessarily eliminate the possibility of longitudinal associations, this finding highlights the importance of considering a model that proposes different developmental mechanisms underlying different patterns of sensory responsiveness.

Sensory seeking was negatively correlated with language quotient scores, as predicted, and showed the same trend for communication adaptive scores. Unlike the results related to social-communicative symptom severity, however, the AD and DD groups in our study did not differ in the association between this sensory pattern and language or communication developmental skill measures. Thus, a developmental model explaining these findings needs to consider why the findings for language and communication developmental skills show a different group pattern than for social-communicative symptoms of autism. We speculated previously that sensory seeking behaviors in children with other DD may differ from those in children with autism and may be more strongly associated with problems in attention disengagement from nonsocial stimuli to shift attention to social stimuli among children with autism. The findings regarding language and communication skills suggest that sensory seeking is associated with delays in acquiring these skills for both groups of children, even after accounting for nonverbal MA. The contrasting pattern of group findings for social-communicative symptoms versus language and communication skills points to the importance of examining symptoms and skills as separate constructs in future research.

Limitations

The present study has several limitations. First, the ultimate goal of our program of research is to refine and test a developmental model of sensory response patterns and their associations with the core features of autism as well as with different domains of developmental/adaptive skills. The current study, however, reflects only a first phase of this research. The findings have implications for our developmental model, supporting our assumptions in some ways and challenging them in other ways. Nevertheless, the results are correlational ones involving concurrently measured behaviors; thus, although our model

proposes some directional influences of sensory patterns on the outcomes we investigated, alternative interpretations of the findings from this study must be considered, including that the social, communication, and language variables in some way account for the patterns of sensory response, or that there are unidentified third variables that account for the associations.

The measurement of severity of social-communicative symptoms of autism is another possible limitation. The ADOS was not created as an instrument to measure symptom severity, but rather as an instrument to indicate whether symptoms reach a threshold supporting a clinical diagnosis of autism. One issue with using the ADOS algorithm scores to index severity is that the modules differ from one another in the activities and “presses” for behavior presented, and the algorithm scores for each module include different items and a different maximum point total. We partially addressed this issue by scaling the scores from Modules 2 and 3 to the range of scores in Module 1 (the most frequently administered module for our sample), but comparing the severity of social-communicative symptoms of autism in a child who is nonverbal to the severity of a child who is speaking in full sentences presents some conceptual challenges. Nevertheless, our clinical impressions affirm that, in general, higher algorithm scores do reflect a more severe manifestation of autism symptoms across the modules, so although this measure may provide an imperfect index, we are confident that it taps meaningful variability in severity of symptoms among our sample.

Every decision about comparison groups in a study such as this is accompanied by limitations. The DD group in this study was heterogeneous in the nature and degree of their developmental disabilities, a design decision made intentionally due to the wide heterogeneity of functioning levels evidenced among children with AD. Eventually, our developmental model may be refined enough to make predictions based on knowledge of different neurodevelopmental mechanisms underlying various disorders or subtypes of disorders (e.g., children with autism compared to children with Williams syndrome). But the field has not yet reached that level of conceptual sophistication related to sensory responsiveness patterns among children with different developmental disabilities.

Conceivably, the lack of differentiation between social and nonsocial stimuli in our measurement model could be a limitation, raising questions about whether the study effects are solely due to children’s responses to social stimuli. Although this issue may warrant additional investigation, past studies cited in the introduction have found that sensory response patterns cross both social and nonsocial stimuli. Specific to the content of the sensory measures used in this study, our research team evaluated the 167 total items from the four measures and identified only 23 items as unambiguously social in nature. Thus, the patterns of association in this study are unlikely to be attributable only to the children’s responses to social stimuli.

Conclusion

Taken together, our findings imply that assessing sensory processing patterns in young children with autism and other DD may promote earlier identification of children with a poor prognosis for later social and/or communicative competence. Further, future communication intervention research could examine the relative efficacy of different strategies to address sensory hypo-responsiveness and/or sensory seeking as important underlying factors influencing language, social and communication development. For example, children with high levels of hypo-responsiveness may benefit from strategies that take advantage of stimuli that have already gained the child’s attention (e.g., by building interactions around the child’s current focus of attention rather than attempting to shift the child’s attention to new stimuli) (Mahoney & Perales, 2003; Siller & Sigman, 2008; Watson, 1998), and/or strategies that enhance the salience of stimuli (e.g., by moving stimuli into the

child's visual field, using gestures, combining multiple modalities, and labeling objects of interest) (Leekam, Hunnisett, & Moore, 1998; Leekam, Lopez, & Moore, 2000; McDuffie, Yoder, & Stone, 2006). Children with high levels of sensory seeking might benefit especially from incorporating idiosyncratic stimuli that motivate them or engage their attention into intervention (Vismara & Lyons, 2007). The more frequent co-occurrence of elevated hyperresponsiveness and hyporesponsiveness in individual children with autism also suggests that clinicians need to be prepared to accommodate co-occurrence of and/or shifting across sensory response patterns in children with autism rather than depending on a single type of accommodation to consistently meet a child's needs to modulate his or her arousal levels. Successfully intervening to modify or accommodate sensory response patterns may contribute to more self-sustaining progress in language, social, and communication development than targeting these skills without considering children's underlying patterns of sensory response.

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Figure 1. Sensory Response Patterns Measurement Model. SPA = Sensory Processing Assessment; TDDT = Tactile Defensiveness and Discrimination Test-Revised; SEQ = Sensory Experiences Questionnaire; SP = Sensory Profile.

Table 1

Participant and Family Demographic Information

	Autism <i>n</i>=72	DD <i>n</i>=44	p
Chronological Age (<i>SD</i>)	52.3 (16.5)	48.1 (22.0)	.259
Mental Age (<i>SD</i>)	32.0 (20.6)	33.4 (17.2)	.913
	<i>n</i> (%)	<i>n</i> (%)	
Gender (male)	61 (85)	25 (57)	<.001
Race			.203
Asian	0 (0)	1 (2)	
Black	8 (11)	3 (7)	
White	57 (79)	36 (82)	
More than 1 race	7 (10)	4 (9)	
Mother's Education			.366
10–11 years	1 (1)	1 (2)	
HS graduate	13 (18)	4 (9)	
Partial college	17 (24)	7 (16)	
College degree	26 (36)	17 (39)	
Graduate degree	15 (21)	15 (34)	

Performance of Children with AD or DD on Sensory, Social-communicative Symptom Severity, Language, and Social and Communication Adaptive Measures

Table 2

Variable	Autism n = 72				DD n = 44			
	Mean	SD	Min	Max	Mean	SD	Min	Max
HYPER	0.28	0.92	-1.95	2.06	-0.46	0.96	-2.45	2.02
HYPO	0.25	1.04	-1.62	3.06	-0.41	0.78	-1.51	1.34
SEEKING	0.27	1.00	-1.37	2.55	-0.45	0.83	-1.41	2.35
ADOS S-C	16.09	4.04	7.64	22.00	4.48	3.24	0.00	15.00
RLQ	54.43	31.89	2.79	113.12	65.27	20.21	24.75	106.59
ELQ	52.83	28.74	10.24	109.03	61.81	18.19	29.15	114.91
LangQ	52.68	30.41	8	111	63.00	18.00	29	108
VABS Soc	66.11	10.59	50	108	74.36	10.64	50	98
VABS Com	67.92	18.07	42	133	69.79	11.16	32	92

Note: HYPER, HYPO, and SEEKING scores are standardized factors scores with a mean of 0 and a standard deviation of 1; ADOS S-C scores are revised social-communication algorithm scores, with Modules 2 and 3 scaled to the possible range of scores for Module 1; RLQ is the computed mean receptive language quotient from the MSEL Receptive Language scale and the PLS4 Auditory Comprehension subscale; ELQ is the computed mean expressive language quotient from the MSEL Expressive Language scale and the PLS4 Expressive Communication subscale; LangQ is the mean total language quotient score from the RLQ and ELQ combined; VABS Soc and VABS Com are the standard scores from the Social and Communication subscales, respectively.

Comparison of AD and DD Groups on Sensory Construct Scores Adjusted for Nonverbal Mental Age and Gender

Table 3

	AD <i>n</i> = 72		DD <i>n</i> = 44		Group Difference	
	Mean	<i>SE</i>	Mean	<i>SE</i>	<i>Diff</i>	<i>p</i>
HYPER	0.23	0.12	-0.38	0.15	0.59	0.19 0.003
HYP0	0.22	0.11	-0.35	0.14	0.57	0.18 0.002
SEEKING	0.27	0.10	-0.43	0.13	0.70	0.17 <.001

Table 4

Association of Sensory Construct Scores with ADOS Social-Communicative Algorithm Scores

Variable	AD vs DD	β	SE	p
HYPER	$p = .56$	-0.043	0.025	0.082
HYPO	$p = .57$	0.048	0.023	0.040
SEEKING	$p = .011$			
AD		0.078	0.025	0.002
DD		-0.041	0.040	0.314

Table 5

Association of Sensory Construct Scores with Aggregate Language Quotient Scores and VABS Social and Communication Adaptive Scores

Aggregate Language Quotient Scores			
<i>Covarying for Gender, Group, and Nonverbal MA</i>			
	β	<i>SE</i>	<i>p</i>
HYPER	−0.002	0.004	0.715
HYPO	−0.010	0.004	0.018
SEEKING	−.011	0.004	0.005
VABS Social Adaptive Scores			
<i>Covarying for Gender, Group, and Nonverbal MA</i>			
	β	<i>SE</i>	<i>p</i>
HYPER	−0.008	0.007	0.263
HYPO	−0.017	0.007	0.011
SEEKING	−0.006	0.007	0.377
VABS Communication Adaptive Scores			
<i>Covarying for Gender, Group, and Nonverbal MA</i>			
	β	<i>SE</i>	<i>p</i>
HYPER	−0.010	0.006	0.118
HYPO	−0.012	0.006	0.052
SEEKING	−0.010	0.006	0.090