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Longitudinal Assessment of Stability of Sensory Features in Children with Autism Spectrum Disorder or Other Developmental Disabilities

Grace T. Baranek[1,a], **Mike Carlson**[1], **John Sideris**[1,a], **Anne V. Kirby**[3,a], **Linda R. Watson**[2], **Kathryn L. Williams**[2], and **John Bulluck**[2]

[(1)]Mrs. T.H. Chan Division of Occupational Science and Occupational Therapy, University of Southern California, 1540 Alcazar St., CHP-133, Los Angeles, CA, 90089-9003, USA

[(2)]Department of Allied Health Sciences, University of North Carolina at Chapel Hill, Bondurant Hall, CB #7120, Chapel Hill, NC, 27599-7120, USA

[(3)]Department of Occupational and Recreational Therapies, University of Utah, 520 Wakara Way, Salt Lake City, UT 84108-1213, USA

Abstract

Prior research on the stability of sensory processing problems in children with autism spectrum disorder (ASD) or other developmental disabilities (DD) has produced inconsistent results. We employed a longitudinal study design to assess the stability of three clinical sensory response patterns: hyporesponsiveness; hyperresponsiveness; and sensory interests, repetitions, and seeking behaviors (SIRS). Parents of children with ASD ($n = 55$) or DD ($n = 35$) responded to sensory questionnaires at two time points (T1 and T2) separated by 3.3 years on average, with the children aged 2–12 years ($M = 5.69 \pm 2.46$) at the first assessment. For each sensory response pattern, regression analysis revealed that, for both ASD and DD groups, scores at T1 were strong predictors of scores at T2. Over the longitudinal assessment interval, there was a significant mean decline in severity for SIRS in both groups and for hyporesponsiveness in the ASD group. Parental estimates of the amount of therapy services received were positively associated with the severity of sensory features at T2, an outcome that may result from increased intervention dosages being administered to children who fail to improve over time. The results are discussed in terms of person-centered and environmental considerations, which, in combination, have the capacity to affect stability outcomes for sensory features.

Lay summary

Children with autism spectrum disorder (ASD) and other developmental disabilities (DD) may process sensory information differently from those who do not have ASD. For example, some children may be over-responsive or under-responsive to sound or touch. In this study, we showed that sensory features in preschool/school-aged children with ASD and DD tend to decrease on

Corresponding author: Grace T. Baranek, 1540 Alcazar St., CHP-133, Los Angeles, CA, 90089-9003, USA, *Phone Number*: 323-442-2875; *Fax Number*: 323-442-1540, chair@chan.usc.edu.

[a]Drs. Baranek, Kirby, and Sideris were formerly at Department of Allied Health Sciences, University of North Carolina at Chapel Hill, Bondurant Hall, CB #7120, Chapel Hill, NC, 27599-7120, USA

average over a several year period. However, individual children tend to retain their ranking (low or high in sensory features) in comparison to other children over time.

Keywords

sensory processing; longitudinal data analysis; autism spectrum disorder; stability; developmental changes

Introduction

Differences in behavioral responses to sensory stimuli have been reported in individuals across a wide range of developmental disabilities (DD), including autism spectrum disorder (ASD). Evidence suggests that as high as 95% of children with ASD experience various sensory features (e.g., Tomchek & Dunn, 2007; Ausderau et al., 2014a; Baranek et al., 2014), and at much higher frequencies than among typically developing children (Ben-Sasson et al., 2009) and children with other types of DD (Rogers et al., 2003; Wiggins et al., 2009; Boyd et al., 2010; Watson et al., 2011). Sensory features have clinical relevance due to their associations with child and family functioning (e.g., Baker et al., 2008; Lane et al., 2010; Schaaf et al., 2011; Bagby et al., 2012; Ben-Sasson et al., 2013) and, in recognition of their diagnostic utility, are used as classification criteria for ASD in the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (American Psychiatric Association., 2013).

Sensory features are often grouped into three multimodal response patterns (Baranek et al., 2014): (a) sensory hyporesponsiveness (i.e., reduced or absent reactions to stimuli); (b) sensory hyperresponsiveness (i.e., heightened sensitivities or aversive reactions to stimuli); and (c) sensory interests, repetitions, and seeking behaviors (SIRS; i.e., intense fascination with specific stimuli, cravings for stimuli, or repetitive sensory-based actions with body parts or objects). The distinction between different features is important because some sensory response patterns, especially hyporesponsiveness (Baranek et al., 2006; Ben-Sasson et al., 2007), may be particularly prominent in children with ASD. Further, specificity of response patterns is critical for research and intervention efforts because such distinctions facilitate sensory-based subtyping (Ausderau et al., 2014a) and permit more refined analyses of interconnections between sensory patterns and key ASD outcomes such as verbal communication (Patten et al., 2013a).

Developmental Trajectories and Stability of Sensory Features

In this study, we address the longitudinal stability of sensory features in children with ASD and DD, along with possible differences in stability between these two groups. These issues are important because maturational processes may strongly affect the behavioral expression of symptoms of ASD and other developmental disorders, as demonstrated in studies tracking related features such as repetitive behaviors (Charman et al., 2005). Moreover, documentation of developmental trajectories establishes a baseline for understanding how therapeutic services may contribute above expected maturational changes in sensory features.

Stability of behavior can be studied in two ways: (a) the ability of early scores to predict later scores (i.e., inter-individual consistency); and (b) the degree of developmental stability or change, as reflected by shifting group-based averages. Most research investigating developmental differences in sensory features among children with ASD has used cross-sectional methodologies. However, cross-sectional studies only address the second aspect of stability (i.e., association with age), and do so indirectly by comparing different cohorts of children, rather than the same cohort over time. Such studies have produced mixed results for the contributions of chronological age (CA) or mental age (MA) to manifestation of sensory features, depending on the age range and comparison groups (e.g., Rogers et al., 2003; Baranek et al., 2006; Ben-Sasson et al., 2009). In two cross-sectional investigations of preschool/school-age samples (Talay-Ongan & Wood, 2000; Liss et al., 2006), sensory hyperresponsiveness was higher in older than younger children. However, most cross-sectional evidence suggests that ASD-related sensory features, including sensory hyperresponsiveness, diminish with age in children (Baranek et al., 2006; Kern et al., 2006; Baranek et al., 2007; Kern et al., 2007a; Kern et al., 2007b; Leekam et al., 2007; Cheung & Siu, 2009) and adults (Kern et al., 2006). Some studies suggest that this reduction is more strongly linked to mental age than to chronological age, perhaps due to maturation of cognitive functions and self-regulation abilities (Baranek et al., 2006; Baranek et al., 2007). Alternately, one meta-analysis (Ben-Sasson et al., 2009) indicates non-linear trends such that some sensory features may increase from birth to six-to-nine years of age and decrease after age nine.

Currently, there is a dearth of longitudinal research on sensory response patterns in children with ASD. In a study of toddlers aged 18–33 months diagnosed with ASD, parent-reported scores for sensory hyperresponsiveness did not change across two time points one year apart (Green et al., 2012). A qualitative study involving retrospective video analysis of infants later diagnosed with ASD (Freuler et al., 2012) suggested that sensory hyporesponsiveness was more salient in infancy, whereas SIRS behaviors became more evident in preschool/school-age children. In a further longitudinal study, McCormick et al. (2016) compared three groups of children aged 2–8 years using a parent-report questionnaire at three time points over 72 months. ASD and DD groups had more sensory features than typically developing controls, and group-based averages for both clinical groups remained elevated over time. Finally, a study by Perez Repetto et al. (2017), in which 34 children with ASD aged 3–4 years were observed over a two-year interval, indicated a lack of change over time for both sensory-specific modalities and more global sensory constructs (e.g., sensory sensitivity). However, the authors noted slight decreases in seven of nine sensory categories, and indicated that the absence of group-based change could reflect a lack of statistical power.

While providing valuable evidence, prior research on the stability of sensory features in children with ASD has been inconclusive due to considerations such as small sample sizes, examination of different age groups, reduced precision associated with cross-sectional designs, and failure to differentiate between specific types of sensory response patterns. There is a need for additional longitudinal research that remedies these issues.

Effects of Therapy Services

Interventions are typically sought by parents of children with ASD or DD to lessen symptoms or improve adaptive functioning. However, intervention effects have largely been ignored in studies measuring stability of sensory features. A wide variety of clinical therapies target sensory features (Uyanik et al., 2003; Lotan & Shapiro, 2005; Schaaf et al., 2014). In light of their multifaceted needs, children with ASD or other DD often receive specialized educational and behavioral programs as well as related services such as occupational therapy (OT), physical therapy (PT), and/or speech-language therapy (ST). OT, PT, and ST are provided with varying intensities and durations across a variety of contexts such as schools, clinics, or home-based programs. Commonly, these therapies include components designed to reduce problematic sensory features and/or their negative impact on participation (Reynolds et al., 2011; Schaaf et al., 2014; Pfeiffer et al., 2018).

Although some authors advocate for intensive early behavioral interventions (e.g., Smith et al., 2000; Dawson et al., 2010; Warren et al., 2011), few studies have examined how therapy services are associated with change in sensory features over an extended longitudinal interval (Case-Smith et al., 2015). Furthermore, the efficacy of sensory-based interventions remains controversial (Dawson & Watling, 2000; Baranek, 2002; Case-Smith & Arbesman, 2008; Lang et al., 2012; Case-Smith et al., 2014), despite their widespread use (Green et al., 2006; Thomas et al., 2007; Patten et al., 2013b). Sensory-based treatments are typically embedded within traditional therapy services, particularly OT (Schaaf & Miller, 2005; American Academy of Pediatrics., 2012) and generally fall into one of two categories: classical sensory integration therapy and other sensory-based interventions (Baranek, 2002; Case-Smith et al., 2015). Whereas classical sensory integration therapy involves child-directed play activities in a clinical setting with specially designed equipment to facilitate multi-modal integration of sensory information in the brain to promote adaptive responses, other sensory-based interventions typically apply more specific adult-directed methods (e.g., weighted vests, sensory diets) and may be incorporated into daily routines such as classroom or home activities (Baranek, 2002; Case-Smith & Arbesman, 2008). Some therapists combine aspects of these two into a more eclectic sensory-based approach (Baranek, 2002; Case-Smith et al., 2015).

Study Purpose

Due to the inconclusive nature of existing studies, there is a need to conduct further longitudinal research on the developmental trajectory of sensory features in ASD. Our study included three aims to address this need: (1) to determine the degree of *inter-individual consistency* of children's sensory response pattern scores (i.e., the extent to which a given child's standing relative to other children adheres over a longitudinal interval); (2) to assess the degree of *consistency over time* in group-based sensory score means for the ASD and DD groups; and (3) to explore the association between traditional therapy services and change in sensory features for children with ASD.

Methods

We implemented a longitudinal design with two waves of data collection from a community sample of children with ASD or DD. Participants were recruited from developmental evaluation clinics, parent support groups, public schools, and a statewide autism research subject registry. Families received monetary incentives for participation ($20–75 plus travel reimbursement). The University's institutional review board approved this research, which adhered to all recommended informed consent/assent and data security procedures.

Participants

The sample included 90 children (ASD, $n = 55$; DD, $n = 35$). All participants were enrolled in the Sensory Experiences Project, which consisted of two sequential five-year phases. Participants in the first phase were initially recruited for a non-longitudinal study, and were assessed only once during this first phase. The second phase, which began shortly after the conclusion of Phase 1, was designed to capture longitudinal data through both (a) reassessing Phase 1 participants and (b) testing new, Phase 2 participants on two occasions. Overall, 48% of children who received an initial assessment (i.e., in either Phase 1 or Phase 2) were reassessed and therefore included.

Children were aged 2–12 years ($M = 5.69 \pm 2.46$) at the first measurement point (T1) and 4–14 years ($M = 9.00 \pm 2.13$) at the second (T2), with time between data collection averaging approximately 3.3 years ($SD = 1.3$; range = 1–6 years). Among children assessed at T1 but not T2, reasons for attrition included loss of contact with family, refused/declined, and relocation. Attrition did not differ significantly between the ASD (55%) and DD (46%) groups. The final ASD and DD sample sizes were adequate to achieve 80% power, given medium effect sizes (.37 to .43) in testing Aims 1 and 2.

Inclusion criteria for the ASD group at T1 consisted of a clinical diagnosis of autistic disorder or ASD by an independent licensed psychologist or physician (e.g., developmental pediatrician, child psychiatrist) and a score at or beyond cut-offs for autism on the Autism Diagnostic Interview-Revised (Rutter et al., 2003) and Autism Diagnostic Observation Schedules (ADOS; Lord et al., 1999). The ADI-R and ADOS were administered by trained research reliable testers.

Children were included in the DD group if at T1 they had overall cognitive delays of two or more standard deviations (SD) below the mean, or two separate areas of development (e.g., visual reception, adaptive behavior) at least 1.5 SD below the mean on a standardized developmental test (Stanford-Binet Intelligence Scales [Roid, 2003]; Mullen Early Learning Scales [Mullen, 1995]; or Vineland Adaptive Behavior Scales [Sparrow et al., 1984]). The DD group included children with known genetic syndromes, idiopathic developmental delays, or delays related to prematurity. Children were excluded from the DD group if they were diagnosed with ASD or met research criteria for autism/autism spectrum on either the ADOS or Childhood Autism Rating Scale (CARS; Schopler et al., 1988). Exclusion criteria for both groups were a diagnosis of fragile-X syndrome, seizure disorder, uncorrected visual or hearing impairment, or physical disability that could interfere with administration of assessments.

Table 1 provides descriptive information about the sample (all assessments noted in Table 1 are described below). Groups were recruited primarily on the basis of chronological age. The percentage of males in the ASD group (83.6%) was similar to the corresponding ASD population proportion of approximately 4:1. As expected, ADOS Severity and IQ were higher for the ASD than DD group.

Instruments

Study assessments were administered by trained research staff during two visits at each measurement point. Assessments relevant to the present analysis included parent-report sensory measures, developmental cognitive assessments, and a structured parent interview about intervention services received. At T1, parents also provided demographic information.

Sensory processing measures—Two questionnaire-based caregiver-report measures of sensory features were used: (a) the Sensory Experiences Questionnaire Version 3.0 (SEQ; Baranek, 2009)—consisting of 105 items rated on a 5-point scale—or an earlier version of the measure which a minority of children received at T1 only, and (b) the Sensory Profile (SP; Dunn, 1999)—consisting of 125 items rated on a 5-point scale. Both instruments assess frequencies of a child's responses to a variety of sensory stimuli across modalities and contexts, and are well-validated measures of their targeted constructs in children with ASD and other DD (Kientz & Dunn, 1997; Little et al., 2011; Ausderau et al., 2014b). The decision to use two measures reflected an attempt to boost measurement reliability by synthesizing the results of a wider overall pool of validated response items pertaining to each sensory construct. Using a procedural strategy described by Watson and colleagues (2011), for each of the sensory constructs we reverse scored the SP to be on the same valence with the SEQ (i.e., higher score indicates more sensory features), adjusted all item scores to fit a 5-point scale, generated factor scores, and created and analyzed standardized scores (mean=0, standard deviation=1). Sample-wide correlations between the two measures were .49, .79, and .71, respectively, for hyporesponsiveness, hyperresponsiveness, and SIRS (all $p < .001$).

Cognitive measures—Children in both groups received a comprehensive standardized cognitive assessment appropriate to their age and developmental level. A non-verbal mental age equivalent (NVMA) was obtained for each child on either the Nonverbal IQ domain of the Stanford-Binet Intelligence Scales (5th Edition; Roid, 2003) or, for lower functioning children, the Visual Reception scale of the Mullen Scales of Early Learning (Mullen, 1995). NVMA scores were used to avoid floor effects on standard scores, and were transformed to a developmental quotient (i.e., IQ proxy score) by dividing NVMA by chronological age and multiplying by 100.

Social responsiveness scale (SRS-2; Constantino & Gruber, 2012).—The SRS-2 was administered to obtain a parental report measure of autism symptom severity across both groups. The SRS-2 is well validated and provides dimensional quantification of autism traits including social-communication and restricted/repetitive behaviors.

Therapy Services Received.—Data on the amounts of therapy received were collected using a structured parent interview conducted by a trained assessor. Dosage of traditional therapies was assessed between T1 and T2, aggregated by type, resulting in the following variables: OT total hours, ST total hours, PT total hours, and total hours of therapy (OT+ST +PT). We further generated the subset of hours of therapy devoted to sensory-based approaches (sensory-based total hours), which were also included in the wider OT, ST, PT, and total hours of therapy categories. Sensory-based approaches were defined as treatments specifically designed to remediate sensory processing difficulties, and included classic sensory integration therapy, sensory diet, auditory integration training, and other sensory-related interventions across therapy types.

Data Analysis

Data were double-entered and error-checked prior to conducting analysis using SAS for Windows, Version 9.3 (SAS Institute Inc., Cary, NC, USA). All predictor variables were mean centered prior to analysis.

To address Aim 1 (inter-individual consistency over time), separately for both the ASD and DD groups we calculated coefficients of stability (zero-order correlation coefficients) between T1 and T2 scores for each sensory response pattern. To further address Aim 1 by enabling greater statistical control, we conducted regression analyses to estimate the extent to which T1 sensory scores predicted T2 scores after adjusting for the following covariates: diagnostic category (ASD vs. DD), interaction between diagnostic category and T1 scores, time elapsed between data collection points, child's age at T1, gender, IQ proxy, household income, and mother's education. Particular covariates were chosen because they either (a) are commonly recognized as important in the literature or (b) could plausibly affect stability outcomes for sensory features. Other potential covariates, such as race or SRS scores, were not selected insofar as they lacked sufficient variability within the sample, were included for descriptive purposes, or could induce collinearity problems if included in the model.

To accomplish Aim 2, pertaining to whether group means shift over time, we performed repeated measures t-tests separately for the ASD and DD groups. For each of the three sensory response patterns, we assessed the significance of mean change in scores between T1 and T2.

To achieve Aim 3, we conducted mediation and moderation analyses to explore the association between therapy dosage and changes in sensory features in the ASD group. Mediation rests on the assumption that both T1 and T2 scores are correlated with the hypothesized mediator, in this case therapy services. Simple bivariate correlations indicated that therapy dosages had small ($r < .15$) non-significant correlations with T1 sensory scores. The weak correlations for T1 sensory scores with therapy led us to conclude that there was insufficient evidence for therapy dosage mediation. Consistent with moderation analysis, there were correlations ($r > .2$) between therapy indicators and T2 sensory scores. Models were then tested looking at main effects of therapy services as well as interactions between therapy dosage and T1 sensory scores as predictors of T2 sensory scores, controlling for the non-diagnostic covariates noted above. Covariate adjustment was employed to enable a more controlled assessment of the various therapies.

Results

Relative to Aim 1, correlation coefficients between T1 and T2 scores were uniformly statistically significant, and were respectively as follows for hyporesponsiveness, hyperresponsiveness, and SIRS: .64, .55, and .63 for the ASD group and .63, .60, and .73 for the DD group. Table 2 presents results for regression analyses of the ability of T1 scores to predict T2 scores. For each sensory pattern, we first tested whether diagnosis moderated the degree of consistency. Results of the interaction between T1 scores and diagnostic group indicated that it did not; therefore, we combined the ASD and DD groups in these analyses. In addition to model parameter estimates, we provided standardized regression weights for pretest scores to aid in interpretability. The results indicated strong, statistically significant relationships between T1 and T2 scores.

Addressing Aim 2, findings regarding mean change in each group over time are shown in Table 3. Sensory scores decreased significantly for hyporesponsiveness in the ASD group and for SIRS in both groups.

With respect to Aim 3, Table 4 provides descriptive data on hours of therapy received, and Table 5 presents models that examine these variables as additional predictors of sensory scores at T2 for the ASD group. For each sensory response pattern, we focused on main effects and interaction terms (T1 sensory score x therapy dosage). T1 sensory scores strongly predicted T2 scores. Because no interaction terms were significant, the results do not support the hypothesis that therapy dosages moderate change in sensory score. However, after statistical adjustments, dosage levels of OT, ST, and total therapies were each associated with increased scores at T2 for all three sensory response patterns. Sensory-based therapies showed a similar pattern, although the effects were in each case nonsignificant.

Discussion

Stability Outcomes

This study provided a longitudinal assessment of the stability of multiple, pan-modal sensory response patterns in children with ASD or DD. Both within and across the two groups, there was a positive association between T1 and T2 scores for each sensory construct. These high correlations are consistent with prior findings for toddlers with ASD (Green et al., 2012), and demonstrate that over a several-year period preschool/school-age children with elevated sensory scores are likely to retain their high standing relative to other children. Analogous to what has been postulated in the area of temperament (e.g., Strelau, 2001; Henderson & Wachs, 2007), inter-individual consistency in sensory response patterns may reflect both: (a) prolonged influence of genetic or neurophysiologic mechanisms linked to ASD or DD, but which nonetheless vary among children (e.g., Marco et al., 2011; Green et al., 2013; Schauder & Bennetto, 2016); and (b) longstanding environmental consistencies, such as parental accommodations or recurring situational parameters that affect the manifestation of sensory features (e.g., Gray, 2006; Brown & Dunn, 2010; Bagby et al., 2012).

Hyporesponsiveness and SIRS diminished over time in the ASD group, representing the first time that such a group-based decline has been documented for sensory features in a longitudinal study. This result is consistent with declines observed in cross-sectional and meta-analytic research (e.g., Kern et al., 2006; Ben-Sasson et al., 2009; Cheung & Siu, 2009). However, our findings diverge from the lack of change reported in prior longitudinal analyses (Green et al., 2012; McCormick et al., 2016; Perez Repetto et al., 2017). One reason for this discrepancy may be our inclusion of a longer follow-up window. Accordingly, our results suggest that, over a several year time span, the potential exists for symptom amelioration during middle or late childhood, a notion consistent with Ben-Sasson et al.'s (2009) meta-analytic findings. As a further explanation for the discrepancy, in some of the previous studies the use of a relatively small sample (e.g., n =17 at follow-up in McCormick et al. [2016]), failure to examine broad-based sensory response patterns that extend across specific sensory modalities (McCormick et al., 2016), or exclusive focus on hyperresponsiveness (Green et al., 2012) may have minimized the chance to document age-based declines. More broadly, we conclude that longitudinal studies that are powered to detect age-based changes for specific sensory response patterns constitute a fruitful means of documenting the circumstances under which either stability or decline is likely to occur.

The attenuation of hyporesponsiveness and SIRS in children with ASD may be explained in part by cortical maturation, particularly involving executive functioning that allows for more selective attention to salient stimuli, flexible behavioral patterns, and better coping strategies (Anderson, 2002; Rueda & Rothbart, 2009). A further mechanism, which could act in concert with maturational readiness, consists of experiential learning that accumulates as the child grows older (e.g., positive reinforcement stemming from repeated engagement with other persons may gradually lessen socially centered hyporesponsiveness). In addition, parents or children may become increasingly adroit in coping efforts to minimize daily lifestyle situations that trigger sensory problems (Gray, 2006; Bagby et al., 2012; Lutz et al., 2012). Examples of such strategies used by parents might include: (a) providing access to more appropriate environments that meet the sensory interests or cravings of the child, so as to progressively diminish unusual SIRS behaviors; or (b) providing salient, multimodal experiences during play and learning opportunities that help children with hyporesponsive behaviors to orient to the most relevant sensory stimuli. Further, normative changes in expected daily activities during middle versus early childhood, such as expectations for engagement in more peer-driven socially appropriate behaviors that provide needed sensory experiences (e.g., trampolines, community recreational activities), could diminish unusual SIRS behaviors. The interactional dynamic between child-centered and environmental variables in affecting sensory responding is an important topic for future research, as greater awareness of such processes can improve therapeutic efforts to reduce sensory problems by targeting family and lifestyle issues.

The remaining sensory response pattern, hyperresponsiveness, did not change significantly over the longitudinal interval, a finding that is more consistent with previous longitudinal studies (Green et al., 2012; Perez Repetto et al., 2017). However, our observed downward trend in hyperresponsiveness, in conjunction with results from the majority of cross-sectional studies, leaves open the possibility that at least moderate reductions in hyperresponsiveness may occur during pre- to school-age years. Additional longitudinal

research is needed to more precisely gauge the extent of, and individual factors contributing to, any such change.

The declines in sensory features that we observed over a roughly three-year period, if extended over longer intervals, suggest that sensory features may continue to diminish over the life course of individuals with ASD. Kern et al.'s (2006) cross-sectional finding of age-related reductions in modality-specific sensory abnormalities from childhood to adulthood is consistent with this notion, although the researchers' use of a sensory measure normed for younger individuals posed a study limitation. One implication of any long-term decline in sensory features is that there may be time-sensitive windows for optimally researching the nature of specific sensory response patterns and that studies of adults may be less sensitive to detecting some sensory differences than those examining children.

Our observed decrease over time in sensory hyporesponsiveness and SIRS in children with ASD may also have diagnostic implications. In particular, the diminution of these features in ASD relative to DD controls may reduce the specificity of these types of sensory features as an indicator of ASD as children grow older. This notion is consistent with findings from a recent epidemiological study of adolescents and adults (mean age for ASD group = 19.1±6.3 years) in which sensory variables evidenced low power in discriminating between individuals with autism and those who were similarly assessed but found not to have a pervasive developmental disorder (Grapel et al., 2015). However, in support of the inclusion of sensory features in the Diagnostic and Statistical Manual of Mental Disorders, our results suggest that the specificity of sensory response patterns, particularly sensory hyporesponsiveness and SIRS, in detecting ASD is likely to be higher when assessing young children (as opposed to adolescents or adults), who comprise the most commonly diagnosed age group. Therefore, studies of sensory features in infants and toddlers should be undertaken to facilitate early detection of ASD, especially given reports of the utility of sensory features in predicting risk for a later diagnosis of ASD (Turner-Brown et al., 2013; Germani et al., 2014) and indications of the precedence of sensory features to later social impairment (Baranek et al., 2017; Damiano-Goodwin et al., 2017).

Outcomes for Therapy Services

Our correlational findings suggest that dosage levels of therapeutic services were oftentimes perplexingly associated with *greater* symptom severity over the study interval. This basic pattern of relationship was robust in that it applied to multiple types of interventions, and was also observed in a series of exploratory analyses that adjusted for alternate sets of variables, corrected for distributional skewness, or used alternate analytic procedures such as simple correlation analysis. Other non-experimental studies, outside of the sensory literature, have failed to show any association between overall amounts of intervention (including special education, OT, ST, and other services) and ASD outcomes over extended time periods (Gabriels et al., 2001; Darrou et al., 2010).

We interpret our finding of positive associations between receipt of services and increases in sensory features to mean that families of children with severe symptoms were likely to secure more services, that service providers applied higher therapy dosages to such children, or that children who received lower therapy dosages tended to have problems more

responsive to intervention. This explanation is consistent with indications from the same sample that children who face challenges that reduce their participation in community activities are likely to receive more treatment (Kirby et al., in press). A second possible explanation is that parents who knew that their children were being treated for sensory problems may have become more aware of such problems over time, leading to more severe ratings along with a more negative result for intervention dosages. Further, our results for therapy dosage may have been influenced by additional concerns such as: (a) use of a study-specific interview to measure intervention receipt; (b) the inability to determine whether the specific treatments were delivered optimally, as considerations such as funding and availability/convenience of therapy may have affected dosage levels; (c) mixing, within tested categories, of therapies that potentially differ in effectiveness (e.g., combining sensory integration therapy with other forms of sensory treatment that have a more restricted evidence base [e.g., Bodison & Parham, 2018; Schaaf et al., 2018]) and (d) service provision to children with low levels of sensory features, for whom intervention was unnecessary.

Due to such interpretational difficulties, additional studies of the long-term effects of therapy services are warranted. In contrast to our negative correlational findings, a number of randomized controlled trials have demonstrated beneficial intervention effects on modality-specific sensory outcomes (e.g., Fazlioğlu & Baran, 2008) or on outcomes related to sensory features such as function and autistic mannerisms (Pfeiffer et al., 2011; Schaaf et al., 2014). Such treatment effects may partially reflect increases in parents' or children's ability to better manage sensory problems (Miller-Kuhaneck & Watling, 2018). Further research is warranted to uncover the role of intervention in affecting the complex array of changes (e.g., maturational, psychological, social-interactional) that create a platform for long-term improvement in sensory outcomes. Our results suggest a need to examine the effects of mixed intervention packages, alternate dosage options, and long-term outcomes in future trials of interventions designed to reduce sensory difficulties.

Limitations

One study limitation pertains to the reliance on parental-report measures of sensory features. Such measures were deemed appropriate because they: (a) have favorable psychometric properties (Dunn, 1999; Baranek et al., 2005; Little et al., 2011); (b) reflect behaviors that occur in real-life contexts over an extended time interval, thereby minimizing situationally specific testing effects; (c) stem from judgments of individuals highly familiar with the child; and (d) correlate positively with direct observational measures (Brock et al., 2012). However, in future research we advocate use of both parental-report and direct assessment strategies when possible, as observational measures possess important strengths such as objectivity and allow for outcome triangulation.

A second limitation pertains to sample attrition, a problem similarly observed in earlier studies of stability in sensory features among children with ASD (McCormick et al., 2016; Perez Repetto et al., 2017). In the present study, the causes of attrition (e.g., family relocation) seemed largely independent of changes in sensory features, and none of the variables in Table 1 predicted attrition at T2. This pattern of results suggests that the determinants of attrition were unlikely to have seriously biased the longitudinal outcomes.

Conclusion

This study indicates that, over a several-year period, preschool/school-age children with ASD: (a) remain stable over time in terms of their inter-individual standing on hyporesponsiveness, hyperresponsiveness and SIRS, but also (b) exhibit group-based declines in some patterns. Along with prior research, our findings point to the possibility of significant long-term improvements in key sensory outcomes among children with ASD. Finally, more longitudinal studies, including randomized controlled trials with lengthy follow-up windows, are needed to better understand the effects of therapy services over extended, several-year time periods.

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Table 1.

Sample Characteristics by Diagnostic Group

Characteristic	ASD (*n* = 55)	DD (*n* = 35)
Gender (male): *n* (%)	46 (83.64)	21 (60.00)
Maternal Education: *n* (%)		
High School or GED	9 (16.36)	9 (25.71)
Associate's Degree or Partial College	7 (12.72)	2 (5.71)
Bachelor's or Master's Degree	37 (67.27)	18 (51.43)
Advanced Degree	2 (3.64)	6 (17.14)
Annual Household Income: *n* (%)		
Less than $59,999	13 (23.63)	16 (45.71)
$60,000 to $99,999	26 (47.27)	9 (25.71)
$100,000 or more	16 (29.09)	9 (25.71)
Unknown	0 (0)	1 (2.86)
Race: *n* (%)		
African American	3 (5.45)	4 (11.42)
White	47 (85.45)	28 (80.00)
Other	5 (9.08)	3 (8.57)
Ethnicity (Hispanic or Latino Origin): *n* (%)	9 (16.36)	1 (2.86)
IQ Proxy (T1)	70.16 ± 26.44	58.34 ± 17.51
T1 CA (years)	5.51 ± 2.22	6.05 ± 2.81
T2 CA (years)	8.98 ± 2.10	9.06 ± 2.21
Mental Age (years; T1)	3.73 ± 2.08	3.30 ± 1.49
Social Responsiveness Scale Total Scores	77.33 ± 10.21	62.81 ± 13.90
ADOS Severity Score	7.95 ± 1.60	1.63 ± 0.83
Sensory Experiences Questionnaire (T1)		
Hyporesponsiveness	2.24 ± 0.70	1.86 ± 0.49
Hyperresponsiveness	2.40 ± 0.53	2.06 ± 0.49
SIRS	2.44 ± 0.55	2.18 ± 0.70
Sensory Profile (T1)		
Hyporesponsiveness	2.32 ± 0.50	2.11 ± 0.50
Hyperresponsiveness	2.16 ± 0.51	1.97 ± 0.50
SIRS	2.37 ± 0.47	2.16 ± 0.53

Note. HYPO = hyporesponsiveness pattern; HYPER = hyperresponsiveness pattern; SIRS = sensory interests repetitions and seeking behaviors pattern; CA = chronological age; T1 = Measurement Time 1; T2 = Measurement Time 2. For continuous variables, tabled entries represent Mean ± SD

Table 2.

Regression Models Testing Stability of Sensory Response Pattern Scores for Combined ASD and DD Groups

	HYPO	HYPER	SIRS
Parameter	**Est (*SE*)**	**Est (*SE*)**	**Est (*SE*)**
T1 Sensory Score	0.71(0.10)*	0.60(0.11)*	0.92(0.14)*
Diagnosis	0.07(0.14)	−0.06(0.16)	−0.10(0.16)
T1 Sensory Score x Diagnosis	−0.06(0.19)	0.07(0.18)	−0.26(0.20)
Model R^2	0.44	0.40	0.46
Model $F(9,75)$	23.07*	18.97*	24.67*
Standardized Beta for T1 Sensory Score	0.68	0.62	0.68

* $p < .001$

Note. HYPO = hyporesponsiveness pattern; HYPER = hyperresponsiveness pattern; SIRS = sensory interests, repetitions and seeking behaviors pattern. Est (*SE*) = parameter estimate (standard error). Dependent variables for all models were T2 (Measurement Time 2) Sensory Scores. Covariates included in all models: elapsed time, age at T1 (Measurement Time 1), gender, IQ proxy, household income, mother's education.

Table 3.

Descriptive Statistics and Tests of Change Over Time by Group for Combined (SEQ and SP) Sensory Scores

			T1 vs. T2 *t*-scores		
	ASD *M* (*SD*)	**DD *M* (*SD*)**	**ASD (54 *df*)**	**DD (34 *df*)**	**Combined (88 *df*)**
HYPO (T1)	0.18 (0.82)	−0.30 (0.66)			
HYPO (T2)	−0.05 (0.87)	−0.31 (0.67)	2.55*	.08	2.17*
HYPER (T1)	0.18 (0.88)	−0.29 (0.86)			
HYPER (T2)	0.03 (0.91)	−0.33 (0.88)	1.35	.32	1.30
SIRS (T1)	0.15 (0.70)	−0.25 (0.85)			
SIRS (T2)	−0.21 (0.97)	−0.61 (0.86)	3.72***	2.97**	4.79***

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

Note. ASD = autism spectrum disorder group (n=55); DD = other developmental disabilities group (n=35); HYPO = hyporesponsiveness pattern; HYPER = hyperresponsiveness pattern; SIRS = sensory interests, repetitions and seeking behaviors pattern; T1 = measurement time 1; T2 = measurement time 2.

Table 4.

Means and Standard Deviations for Therapy Service Dosages within ASD Group (n = 55)

	Total Hours Recieved[1]		Hours Per Week	
	***M* (*SD*)**	**Range**	***M* (*SD*)**	**Range**
Occupational therapy (OT)	114.87 (111.85)	0 – 433	0.63 (0.53)	0 – 1.95
Physical therapy (PT)	11.55 (42.21)	0 – 224	0.05 (0.17)	0 – 0.96
Speech-language therapy (ST)	201.61 (187.55)	0 – 852	1.09 (0.89)	0 – 3.85
Traditional therapies	328.03 (265.41)	0 – 1165	1.77 (1.20)	0 – 5.53
Sensory-based therapies	113.93 (148.88)	0 – 763	0.67 (0.82)	0 3.50

[1] Time between observations ranged from 1.4 to 9.1 years.

Table 5.

Regression Models Including Therapy Dosage Variables and Interaction Terms in ASD Group

	OT Total	PT Total	ST Total	Therapies Total	Sensory-Based Total
	Est (*SE*)	**Est (*SE*)**	**Est (*SE*)**	**Est (*SE*)**	**Est (*SE*)**
Dependent variable: T2 HYPO					
Parameter					
T1 HYPO	0.68 (0.11) ***	0.67 (0.13) ***	0.63 (0.11) ***	0.64 (0.11) ***	0.67 (0.12) ***
Therapy Dosage	0.003 (0.001) **	−0.001 (0.004)	0.002 (0.001) *	0.001 (0.0004) **	0.001 (0.001)
Interaction	0.01 (0.06)	−0.13 (0.28)	0.02 (0.04)	0.00 (0.03)	−0.03 (0.05)
Standardized Beta					
T1 HYPO	0.64 (0.11)	0.63 (0.12)	0.60 (0.11)	0.6 (0.10)	0.63 (0.11)
Therapy Dosage	0.34 (0.12)	−0.04 (0.17)	0.34 (0.13)	0.43 (0.13)	0.16 (0.13)
Dependent variable: T2 HYPER					
Parameter					
T1 HYPER	0.66 (0.13) ***	0.71 (0.13) ***	0.74 (0.13) ***	0.71 (0.12) ***	0.7 (0.13) ***
Therapy Dosage	0.003 (0.001) *	−0.002 (0.003)	0.002 (0.001) **	0.002 (0.001) **	0.001 (0.001)
Interaction	−0.08 (0.07)	0.27 (0.28)	−0.04 (0.03)	−0.04 (0.02)	−0.01 (0.04)
Standardized Beta					
T1 HYPER	0.64 (0.12)	0.69 (0.13)	0.72 (0.12)	0.69 (0.12)	0.68 (0.13)
Therapy Dosage	0.34 (0.14)	−0.1 (0.12)	0.38 (0.14)	0.47 (0.15)	0.17 (0.16)
Dependent variable: T2 SIRS					
Parameter					
T1 SIRS	0.92 (0.16) ***	0.93 (0.18) ***	0.85 (0.16) ***	0.87 (0.16) ***	0.9 (0.16) ***
Therapy Dosage	0.003 (0.001) *	0.001 (0.003)	0.002 (0.001) *	0.001 (0.001) **	0.002 (0.001)
Interaction	−0.07 (0.06)	0.09 (0.29)	−0.06 (0.05)	−0.05 (0.03)	−0.06 (0.06)
Standardized Beta					
T1 SIRS	0.66 (0.12)	0.67 (0.13)	0.61 (0.12)	0.63 (0.11)	0.65 (0.12)
Therapy Dosage	0.29 (0.13)	0.03 (0.14)	0.31 (0.14)	0.40 (0.14)	0.24 (0.13)

* $p < 0.05$

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** $p < 0.01$

*** $p < 0.001$

Note. ASD = autism spectrum disorder; HYPO = hyporesponsiveness pattern; HYPER = hyperresponsiveness pattern; SIRS = sensory interests repetitions and seeking behaviors pattern; OT = occupational therapy; PT = physical therapy; ST = speech-language therapy. Interaction terms represent T1 Sensory Score X Therapy Dosage; Est (*SE*) = parameter estimate (standard error). Covariates included in all models: elapsed time, age at T1, gender, IQ proxy, household income, mother's education. Therapy dosage is scaled in hours of service. For example, for each additional hour of OT service, we expect a . 003 increase in HYPO score. Table is best viewed in a separate window.