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Sensory Subtypes in Children with Autism Spectrum Disorder: Latent Profile Transition Analysis using a National Survey of Sensory Features

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Abstract

Background—Sensory features are highly prevalent and heterogeneous among children with ASD. There is a need to identify homogenous groups of children with ASD based on sensory features (i.e., sensory subtypes) to inform research and treatment.

Methods—Sensory subtypes and their stability over one year were identified through latent profile transition analysis (LPTA) among a national sample of children with ASD. Data were collected from caregivers of children with ASD ages 2-12 years at two time points (Time 1 N=1294; Time 2 N=884).

Results—Four sensory subtypes (Mild; Sensitive-Distressed; Attenuated-Preoccupied; Extreme-Mixed) were identified, which were supported by fit indices from the LPTA as well as current theoretical models that inform clinical practice. The Mild and Extreme-Mixed subtypes reflected quantitatively different sensory profiles, while the Sensitive-Distressed and Attenuated-Preoccupied subtypes reflected qualitatively different profiles. Further, subtypes reflected differential child (i.e., gender, developmental age, chronological age, autism severity) and family (i.e., income, mother's education) characteristics. Ninety-one percent of participants remained stable in their subtypes over one year.

Conclusions—Characterizing the nature of homogenous sensory subtypes may facilitate assessment and intervention, as well as potentially inform biological mechanisms.

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Keywords

children; autism; sensory; latent profile transition analysis; subtypes

Introduction

A variety of sensory features are often reported in children with autism spectrum disorder (ASD) (Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson, et al., 2009; O'Donnell, Deitz, Kartin, Nalty, & Dawson, 2012), and are associated with core characteristics of the disorder (Boyd et al., 2010; Lane, Young, Baker, & Angley, 2010; Watson et al., 2011). Sensory features are often described as constellating into distinctive behavioral constructs or sensory response patterns across modalities; these may include: hyporesponsiveness (HYPO); hyperresponsiveness (HYPER); sensory interests, repetitions, and seeking behaviors (SIRS); and enhanced perception (EP). HYPO is considered a lack of or delayed response to sensory stimuli (e.g., a lack of orienting to loud sounds, slow to react to pain) (e.g., Baranek et al., 2013; Ben-Sasson et al., 2009). HYPER is defined by an exaggerated or avoidant response to sensory stimuli (e.g., distress during grooming, aversion to sounds) (e.g., Baranek et al., 2007; Schoen, Miller, & Green, 2008). SIRS is characterized by a fascination with or craving of sensory stimulation that is intense and may be repetitive in nature (e.g., fascination with visual or tactile stimuli) (e.g., Ben-Sasson et al., 2007; Liss, Saulnier, Fein, & Kinsbourne, 2006). EP is characterized by superior acuity in the awareness of specific sensory stimuli and focus on specific elements of stimuli (e.g., recognizing perfect pitch, superior ability to recognize visual patterns) (e.g., Happé & Frith, 2006; Mottron, Dawson, & Soulières, 2009).

Although distinct sensory response patterns can be identified across studies using various instruments, these patterns are also known to co-occur (e.g., HYPO and HYPER) in children with ASD (Ausderau et al., 2013; Baranek et al., 2006; Lane et al., 2010; Liss et al., 2006). Such heterogeneity of sensory features across and within children poses challenges for understanding pathogenesis as well as intervention planning. New definitions for ASD (DSM-5 American Psychiatric Association, 2013) incorporate sensory features as characteristic of the disorder, but include all sensory response patterns within the same symptom domain of “restricted, repetitive patterns of behavior, interests of activities” without differentiation of subtypes, and without recognition of potential associations with the “social communication and social interaction” symptom domain.

One effective approach to characterizing the co-occurrence of behavioral patterns is using person-centered methods (Macy, 2008; Neely-Barnes, 2010) such as latent profile analysis (LPA) and latent profile transition analysis (LPTA). LPA creates smaller, more homogeneous groups of individuals with similar scores (i.e., subtypes) that are derived from large heterogeneous samples (Muthén & Muthén, 2010). LPTA allows examination of these subtypes over time, estimating their stability. Identifying subtypes has had profound effects for understanding pathogenesis, prognosis, and the development of targeted intervention approaches in other clinical populations (e.g., Grizenko, Pereira, & Joober, 2013; Larsson, Lichtenstein, & Larsson, 2006).

Previous research on subtypes of children with ASD based on sensory features is limited to three studies (all using versions of the Sensory Profile) yielding mixed findings. Using cluster analysis with 54 children with ASD between the ages of 2 to 10, Lane and colleagues (2010) found three subtypes (i.e., Sensory-based Inattentive Seeking; Sensory Modulation with Movement Sensitivity; Sensory Modulation with Taste/Smell Sensitivity) using the seven sensory domains from the Short Sensory Profile (McIntosh, Miller, & Shyu, 1999). In a later follow up investigation with 29 children with ASD, these same investigators (Lane, Dennis, & Geraghty, 2011) further parsed the Sensory-based Inattentive Seeking and Sensory Modulation with Movement group into two subtypes, suggesting a total of five subtypes may characterize ASD. The sensory subtypes identified differed primarily with regard to severity and modality (movement v. taste/smell). Liss and colleagues (2006) explored patterns of sensation and attention, specifically an "overfocused" pattern, in 144 children with ASD (mean age = 8.5 years). They combined parent report measures of symptom severity, overselective attention, exceptional memory, adaptive behaviors, and sensory features. An expanded version of the Sensory Profile questionnaire was created for the study to measure sensory features (e.g., overreactivity, underreactivity, and seeking behaviors) (Dunn, 1999; Liss, Saulnier, & Fein, 1998). Four subtypes emerged from the cluster analysis (Overfocused; No Sensory Problems; Low Functioning; Mildly Overfocused); Overfocused in a mild or severe form comprised 43% of their sample. While these studies provide support for subtyping on the basis of sensory features, methodological constraints (e.g., small sample sizes, varying measurement tools, and conflated co-occurring sensory patterns within the same subscales) suggest the need for further research. Furthermore, there are no studies corroborating findings using other measures.

A large-scale study is needed to better address the challenging heterogeneous presentation of sensory features in ASD, in order to determine more homogeneous sensory subtypes and their stability over time. Detailed profiling will promote understanding of characteristics related to specific sensory subtypes that may facilitate clinical assessment and intervention planning, as well as inform potential biomarkers in future research. Specific research aims addressed in this study included:

1. To determine sensory subtypes in a population of children with ASD ages 2-12 years using the Sensory Experiences Questionnaire.
2. To determine the stability of sensory subtypes over one year.
3. To describe child characteristics and family demographics of sensory subtypes.

Methods

A longitudinal online survey was conducted with a national sample across two time points, one year apart. Participants were recruited with the assistance of two autism research registries and online autism advocacy organizations. Participants were screened for inclusion/exclusion criteria before initiation of the survey. Eligible respondents were sent an electronic invitation to participate, plus up to three prompts to complete it. Participants were sent a follow up survey exactly one year after completion of the initial survey. Families were offered a $5.00 gift card at each time point.

Participants were asked to complete the Background Information Questionnaire (BIQ), Sensory Experience Questionnaire-3.0 (SEQ-3.0; Baranek, 2009), and the Social Responsiveness Scale (SRS Constantino & Gruber, 2005) or the Social Responsiveness Scale-Preschool (SRS-P Pine, Luby, Abbacchi, & Constantino, 2006) at Time 1. At the one-year follow up (Time 2), participants were asked to complete the Background Information Questionnaire-Updated (BIQ-U) and SEQ 3.0. All questionnaires were converted to an electronic format using Qualtrics software (Qualtrics Labs, 2011) and the online versions of the surveys were approved by the publisher or author before administration. Upon request, five surveys were distributed and completed in paper format. The study was approved by the university's Institutional Review Board and caregivers gave informed consent electronically.

Participants

Participants were 1407 caregivers (mothers [95.1%], fathers [3.3%], other caregivers [1.6%] that lived in the home) of children with ASD (i.e., diagnosis of Autistic Disorder, Asperger's Disorder, or Pervasive Developmental Disorder-Not Otherwise Specified [PDD-NOS]) (American Psychiatric Association, 2000), between the ages of 2 to 12 years. Seventy-two percent of the Time 1 participants (N=936) responded to the follow-up survey one year later. The child's primary diagnosis was collected via caregiver report. Approximately 50% of the sample was recruited through the national web-based autism registry, IAN, which recently authenticated the parent-report ASD diagnosis of a sub-sample of their registry through a review of medical records (Daniels et al., 2012). The remainder of participants was recruited using online recruitment material through a university research registry, online autism advocacy and parent support groups. We also collected data to characterize autism severity (see below). After filtering for exclusion criteria and incomplete data, the final sample included 1294 children at Time 1 and 884 at Time 2 (one year later).

Exclusionary criteria for the study included the following: co-morbid conditions of ASD such as fragile × syndrome and tuberous sclerosis, genetic disorder or syndrome associated with a developmental disability, severe physical impairment, significant visual or hearing impairment, traumatic brain injury or brain malformation, psychotic diagnosis, and seizures within the last 12 months. Table 1 summarizes child and family characteristics.

Study Instruments

The Sensory Experiences Questionnaire Version 3.0 (Baranek, 2009) is a 105 item caregiver report instrument designed to characterize sensory features in children ages 2-12 years with ASD and/or developmental disabilities in social and non-social contexts. This instrument has well-established reliability and validity in many studies (e.g., Ausderau et al., 2013; Baranek et al., 2006; Boyd et al., 2010; Little et al., 2011; Watson et al., 2011). The SEQ 3.0 has been revised from previous versions (SEQ 1.0, 2.1) to match an evolving conceptual model, including the addition of a enhanced perception construct, and expanding, refining, and distributing items across sensory response patterns, sensory modalities, and contexts (social and non-social) as well as adding control items (see Ausderau et al., 2013, for a review of the development of the SEQ 3.0). The SEQ 3.0 items measure the frequency of sensory behaviors across sensory response patterns, modalities, and social or non-social contexts. The first 97 items measure the frequency using a 5-point Likert-type scale ranging from 1 (almost never) to 5 (almost always) with a higher score indicating more sensory features. The last eight items ask broader questions about the child's sensory features and allow the caregiver to elaborate with a qualitative response; these were not included in the factor analysis. A factor analysis (N=1307), confirmed the presence of four sensory factors in the SEQ 3.0 (HYPO, HYPER, SIRS, and EP) [Chi-Square 16, 724.18 (3984)**; RMSEA=.051 (.050 to .052); SRMR=.07] (Ausderau et al., 2013). The four sensory factor scores were used as the dependent variables in the LPTA.

Autism symptom severity was assessed using the Social Responsiveness Scale (Constantino & Gruber, 2005) for ages 4 to 18 and Social Responsiveness Scale-Preschool Version (Pine et al., 2006) for ages 35 to 48 months. The SRS-P was administered to our participants with children ages 2-3 years. The SRS and SRS-P have 65 items, which are quantitative trait measures of children's autism symptoms in social settings with higher scores indicating more autistic symptoms. Total scores were used as a covariate in the LPTA analysis to allow for a direct comparison of the measures, as the SRS-P was in prepublication.

A Background Information Questionnaire (unpublished) was developed specifically for this study to obtain information about the child and family in four domains: family characteristics, child characteristics, child's functioning level, and intervention services. Demographic and developmental variables were derived from the BIQ to provide descriptive data regarding key child and family characteristics as well as to be used as covariates in the LPTA analysis. *Autism diagnosis* included Autism/Autistic Disorder, Asperger's Disorder, and PDD-NOS. Diagnosis was obtained per caregiver report for all participants; a subset included previously authenticated diagnoses through a registry (Daniels et al., 2012). *Household income (HH income)* was reported in increments of $20,000, ranging from < $20,000 to >$100,000 and the analysis used the floor of each income category. *Maternal Education* was recoded to a dichotomous variable indicating whether the child's mother had received a bachelor's degree or higher. *Race* was recoded as a dichotomous variable indicating white or non-white due to the small number of participants in the other categories (see Table 1). *Chronological Age (CA)* was calculated using the child's birth date and was measured in months. *Parent Estimated Developmental Age* (PEDA) of the child as reported by caregivers and indicating the child's “current overall level of cognitive functioning” measured in 6 month increments between <12 months to 3 years, and 12 month increments between 3 to 19 years was collected. *IQ Proxy* was calculated from this estimate using the following formula (i.e., [PEDA/CA]*100). This was done to obtain a standardized metric for all participants that would not be correlated with CA to use in the analyses. A subset of the sample (n=316) whose parents provided results from standardized IQ tests children had received in past years, were found to be positively correlated with the calculated IQ proxy (r=.67). Given these test scores were not recent, this correlation indicated sufficient stability.

Data Analysis

All analyses were run in Mplus version 6.1 (Muthén & Muthén, 2010). Data analysis occurred in phases described in detail below. For research aims 1 and 2, factor scores from a confirmatory factor analysis (CFA) with the SEQ 3.0, using Likert-type scale items 1 through 97, were computed such that a zero for each of the four sensory response patterns

(HYPO; HYPER; SIRS; EP) was the mean for our sample of children with ASD (Ausderau et al., 2013). The factor scores from both time points served as the manifest variables in the analysis of latent profiles.

Latent Profile Analysis—The LPA was run on Time 1 and Time 2 data using SEQ sensory pattern (HYPO; HYPER; SIRS; EP) factor scores without covariates. Fit statistics were examined for two to five profile solutions. Five commonly used measures were considered in choosing the appropriate solution: the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), Entropy, a Lo-Mendell Rubin Test (LMR), and a Bootstrap Likelihood Ratio Test (BLRT) (Lo, Mendell, & Rubin, 2001; Nylund, Asparouhov, & Muthén, 2007; Thompson, Macy, & Fraser, 2011). These methods enable the researcher to test the changes in model fit as the number of profiles (e.g. four versus five profile solution) varies. The BLRT and LMR provide methods for testing whether there is a significant improvement in model fit with the addition of more profiles. AIC and the BIC are comparative fit measures used to assess model fit by simple changes in the magnitude of the index, rather than by comparison to a standard value. Entropy is a measure, bounded at zero and one, of the certainty with which observations are assigned to group with higher values indicating more certain fit. The fit measures, parsimony consideration, and previous literature and hypotheses concerning sensory phenotypes in children with autism were used as evidence to determine the optimal solution (Nylund et al., 2007). Similar analyses were repeated on the Time 2 data in order to examine the stability of sensory subtypes at the second time point. Both results (LPA Time 1 and Time 2) were taken into consideration when determining the appropriate solution (i.e. number of sensory subtypes).

The LPAs were run again for the Time 1 and 2 data with covariates (i.e., autism severity, IQ proxy, CA, gender, HH income, and mother's education). Solutions were examined for three to five profiles using the same fit statistics (i.e., AIC, BIC, Entropy, LMR, and BLRT).

Latent Profile Transition Analysis—LPTA estimates a solution based on data from both time points (Time 1 N=1294; Time 2 N=884) simultaneously, while also providing data on participants' transitions between profiles over time (Collins & Lanza, 2010). The LPTA was run initially with the supported solutions (e.g. four profile solution) without covariates using similar fit statistics (i.e., AIC, BIC, Entropy, BLRT). Full information maximum likelihood (FIML) within Mplus was used to estimate the missing sensory pattern factor scores at Time 2 (Allison, 2001; Schafer & Graham, 2002). Solutions from the Time 1 and Time 2 LPA and from the LPTA all suggested a four profile solution. Finally, we added the covariates to a four profile solution model to test whether they accounted for the profiles found in the latent models and whether their presence impacted the stability of the model. Descriptive statistics were computed on sensory subtypes and transitioning groups.

Posterior Probabilities—The posterior probabilities were exported for analysis from the final LPTA four profile (sensory subtypes) solution with covariates. In models of categorical latent variables, posterior probabilities serve the same role as factor scores in models of continuous latent variables (Nylund et al., 2007): they provide a measure of the participant on that latent variable.

Attrition Analysis—Attrition analysis was completed on the non-responders (32%) at Time 2 to test for the possibility of differential data loss by key study variables (autism severity, IQ proxy, HH income, mother's education, and CA).

Results

Latent Profile Analysis

At Time 1 and 2, we tested LPA solutions for up to five profiles. Parsimony, fit statistics, and substantive meaning of profiles were all evaluated when considering which model to retain. While models with lower AIC and BIC are preferred, the magnitude of change in these metrics is examined as well. Considering the magnitude of change, four profiles were preferred as change was less significant or stable when moving from four to five profiles. Regarding entropy, a higher value is preferred, so again the change between the profiles pointed toward four profiles. When considering LMR and BLRT, the lack of significance when moving from four to five profiles at Time 1, indicated the 5 profile solution didn't necessarily fit the data better, but the same transition for the Time 2 data was significant. In summary, there was significant improvement in model fit with the addition of up to four groups. However, the addition of a fifth group did not provide improvement in model fit (considering all fit statistics) nor a match to theoretical hypotheses. See Table 2 for the fit indices for the Time 1 and 2 LPA solutions. The four profile solution was retained based on theoretical grounds, parsimony, and fit statistics (see Figure 1).

Latent Profile Transition Analysis

Given the model was largely stable and a four profile solution was supported at both time points, analysis proceeded to the transition analysis. The LPTA was run with three to five profile solutions to confirm fit statistics for the same four distinct profiles (sensory subtypes) found in the data from Time 1 and Time 2 LPA. The four-profile solution was supported by statistical measures as well as theoretical and clinical reasoning. The covariates continued to improve the statistical fit of the four profile solution. See Table 3 for statistical fit measures for the LTPA solutions with three to five profiles (N=1294) as well as four profiles with covariates (N=1058)[1]. The four profile solution was retained as the change in magnitude for the AIC and BIC decreased between the four and five profile solutions and the entropy peaked at four profiles. The Mild Subtype, (N=308, 29%) describes children who scored low on all sensory patterns, while those in the Extreme-Mixed Subtype (N=182, 17%) showed a profile with high scores in all four sensory patterns. The remaining two subtypes showed a split in their factor scores. The Sensitive-Distressed Subtype (N=291, 28%) scored close to the mean on all patterns, with lower factor scores on HYPO and SIRS, and higher scores on HYPER and EP. The Attenuated-Preoccupied Subtype (N=179, 17%) had the opposite pattern; this subtype showed lower scores on HYPER and EP and higher scores on HYPO and SIRS (see Figure 2).

[1]The sample size decreased for this analysis. While FIML will replace missing data on the variables involved in the estimation of the profiles, in the case the factor scores, missing data on the covariates remains missing.

To test for the possible impact of subjects being recruited from different sources (IAN and non-IAN), we ran a generalized logistic model controlling for covariates (i.e., autism severity, IQ proxy, CA, gender, HH income, and mother's education) to examine if the recruitment source predicted subtype membership. The findings for IAN membership were not significant (3 df, n=960), chisquare=2.9118, p=.4054.

Ninety-one percent (N=960) of participants were stable in their sensory subtype between time points. The largest group (N=49, 5%) that did transition between time points moved from the Sensitive-Distressed to the Mild Subtype. The remaining transition groups were smaller, ranging from N=1 to N=25. See Table 4 for characteristics of participants in stable sensory subtypes and Table 5 for characteristics of participants that transitioned between subtypes.

Posterior Probability of Membership

The posterior probabilities indicate the likelihood of assignment to a profile. Posterior probabilities range from zero to one with higher values representing a greater likelihood of correct assignment to a category. They are continuous measures of group membership; high posterior probabilities allow individuals to be classified into groups with a greater degree of certainty (Collins & Lanza, 2010). Nagin (2005) suggests posterior probabilities >70% indicate profile membership confidence; the posterior probabilities for the sensory subtypes' membership all were higher than this value (Mild Subtype; 94%, Sensitive-Distressed Subtype; 84%, Attenuated-Preoccupied Subtype; 92%, Extreme-Mixed Subtype; 85%).

Attrition Analysis

Sixty-eight percent participated in the longitudinal follow up. We tested for the possibility of differential data loss (attritors) by key study variables (autism severity, IQ proxy, HH income, mother's education, and CA), using a logistic model with attrition (attritor v. non-attritor) as the outcome. We predicted attrition as a function of the SEQ 3.0 factor scores and the model covariates. The model accounted for a very small proportion of the variance, pseudo $R^2 = .04$, although it was statistically significant [chi-square (10) = 54.96, $p < .001$)]. Due to this small effect, we concluded that the sample was stable from time one to two with regard to key study variables.

Discussion

Novel findings from this study found four sensory subtypes (Mild; Sensitive-Distressed; Attenuated-Preoccupied; Extreme-Mixed) characterized children with ASD in a national sample. These four clinically distinct and homogeneous sensory subtypes were also shown to be stable (91%) over one year. The LPA and LPTA models demonstrated good fit statistics, high posterior probabilities within subtype, and consistency with the literature. The subtypes varied in their descriptive characteristics. Interestingly, the children who had the most intense and comprehensive array of sensory features, the Extreme-Mixed Subtype, also had the highest level of autistic traits, but they were very similar in age and IQ proxy to the subtype with the lowest sensory symptoms, the Mild Subtype. Additionally, the Attenuated-Preoccupied Subtype (increased levels of HYPO and SIRS) had the second highest autistic traits, but had the lowest IQ proxy and they were much younger than all the other subtypes. The differential representation of child and family characteristics by sensory subtype further supports distinct sensory subtypes but also requires further investigation to explain these relationships.

Although previous research has explicated various sensory response patterns across children with ASD (Ausderau et al., 2013; Boyd et al., 2010; Lane et al., 2010; Liss et al., 2006; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006), the current findings suggest that four sensory subtypes capture the heterogeneity and co-occurrence of these sensory response patterns among meaningful clinical groupings. Our results are consistent with previous literature showing the co-occurrence of HYPER and HYPO among children with ASD (Baranek et al., 2006; Ben-Sasson et al., 2007); however, our findings further this literature by suggesting that HYPER and HYPO co-occur among the Extreme-Mixed Subtype only. Likewise, increased levels of HYPER or HYPO differentiated the Sensitive-Distressed and Attenuated-Preoccupied Subtypes respectively, indicating qualitatively different subtypes. SIRS, specifically sensory seeking, has been found to be differentially associated with HYPER and HYPO (Boyd et al., 2010; Gabriels et al., 2008), with research suggesting that SIRS may serve different functions (e.g., arousal modulation) in the presence of HYPER versus HYPO. The current findings suggest that SIRS is associated with both HYPO in the Attenuated-Preoccupied Subtype and HYPER in the Extreme-Mixed Subtype, which may contribute to understanding differing functions of SIRS across subtypes. Strong associations of HYPO with SIRS, as well as HYPER with EP, could be seen within the four sensory subtypes, which further adds to the literature about the inter-relationships of these sensory patterns and their qualitatively different presentations.

Although subtyping has been attempted with small cross-sectional samples (Lane et al., 2011; Lane et al., 2010; Liss et al., 2006), this study is the first to use longitudinal data from a large national heterogeneous sample of children with ASD for sensory subtyping analyses. Moreover, subtypes were derived solely from a new sensory measurement tool (e.g. SEQ-3.0) validated on children with ASD, using the four distinct sensory patterns (HYPO; HYPER; SIRS; EP) that have been most commonly characterized in the literature (Ausderau et al., 2013; Baranek et al., 2006; Ben-Sasson et al., 2009; Mottron et al., 2006; Reynolds & Lane, 2008). While future studies are needed to unravel reasons for differences in sensory subtype classifications across studies (e.g., sampling characteristics, measurement tools), similarities in our findings with other studies (e.g., identification of a subtype with overall mild sensory features) (Lane et al., 2011; Lane et al., 2010; Liss et al., 2006) provide further convergent validity.

Identification of homogeneous sensory phenotypes as isolated by this research has implications for neurobiological studies that aim to link sensory features with specific underlying mechanisms. For reviews of the neurophysiological literature related to the underlying sensory constructs (HYPO, HYPER, SIRS, and EP), please see Baranek et al. (in press), Bomba & Pang (2004), Jeste & Nelson (2009), and Marco et al. (2011). Specifically, future studies using non-invasive brain imaging methods and electrophysiological recording methods can map the neurophysiological correlates of the distinct subtypes, as well as track the stability or change in these features through maturation or intervention.

Although our findings indicated that subtypes were 90% stable over time, the individuals showing transitions over time were small and thus only descriptive analyses were possible. Seven different transition patterns were observed ranging in size from one to 49 children. However, one observation is the majority of children who do transition (N=89/98) are moving out of the Extreme-Mixed and Sensitive-Distressed Subtypes to groups that may be considered less impaired (Extreme →Sensitive-Distressed and Attenuated-Preoccupied Subtypes; Sensitive-Distressed→Mild Subtype). The movement to a “less impaired” subtype would suggest improvement due to treatment, maturation, or potentially other variables.

Currently, a variety of intervention approaches targeting sensory features in children with ASD have proliferated in clinical settings although efficacy research is limited (American Academy of Pediatrics, 2012; Baranek, 2002; May-Benson & Koomar, 2010). Due to the heterogeneous nature of ASD and sensory features, children's responses to interventions are likely to be individualized and varied. The identification of homogeneous sensory subtypes provides an opportunity for more rigorous studies examining the efficacy of interventions precisely targeted to specific clinical profiles.

Conclusion and Limitations

In conclusion, this study is the first of its kind to identify sensory subtypes specific to children with ASD in a large-scale national survey. Although online recruitment and survey administration allowed for a large and heterogeneous sample, future studies could augment caregiver report data with behavioral observations to further validate subtypes as well as provide more definitive diagnostic confirmation. In addition, using a stratified sample would be useful in future studies to more comprehensively explore demographic characteristics associated with specific sensory subtypes. Future studies should examine the stability of the subtypes beyond one year to further illuminate the developmental nature of sensory features and factors affecting changes over time. In addition, studies are needed to determine differences in child functional outcomes, including adaptive behavior, as well as effects on family outcomes (e.g., quality of life, parenting stress) among these sensory subtypes. Such research would further facilitate the development of more precise intervention strategies targeted to each subtype in the context of sensory challenges presenting in daily life and impacting on social participation.

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Key Points

- Sensory features are prevalent but heterogeneous in children with ASD.
- Four homogeneous sensory subtypes (Mild; Sensitive-Distressed; Attenuated-Preoccupied; Extreme-Mixed) were identified in children with ASD, ages 2-12 years, using latent profile transition analysis.
- The Mild and Extreme-Mixed subtypes reflected quantitatively different sensory profiles, while the Sensitive-Distressed and Attenuated-Preoccupied subtypes reflected qualitatively differences.
- Sensory subtypes were 91% stable over one year.
- Identification of homogenous sensory subtypes may facilitate assessment and intervention, as well as potentially inform biological mechanisms.

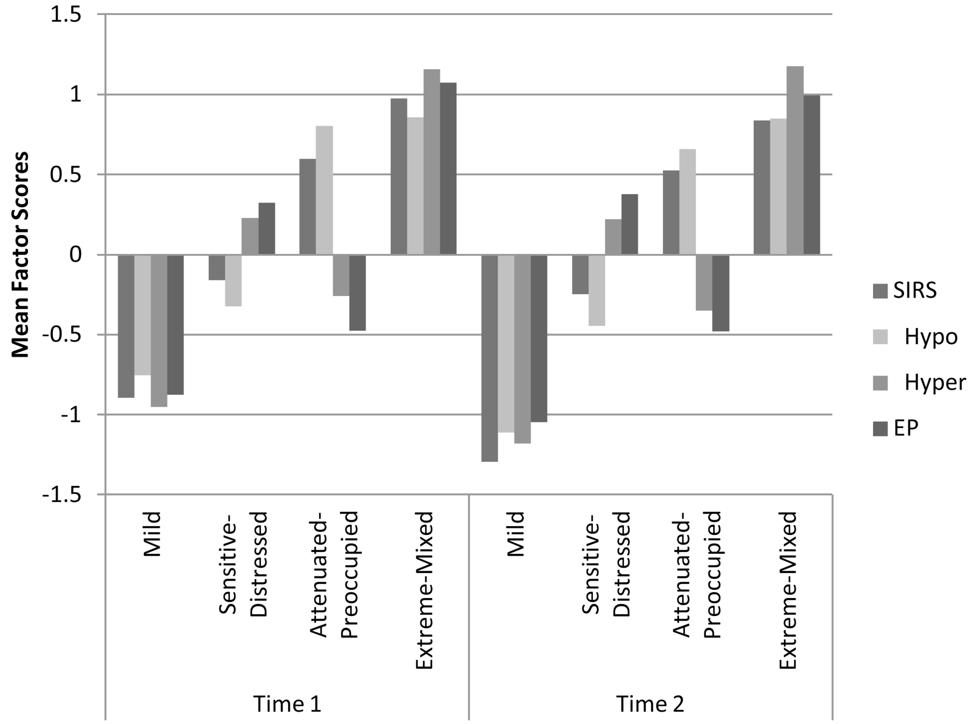

Figure 1. Latent Profile Analysis Using Cross-Sectional Data

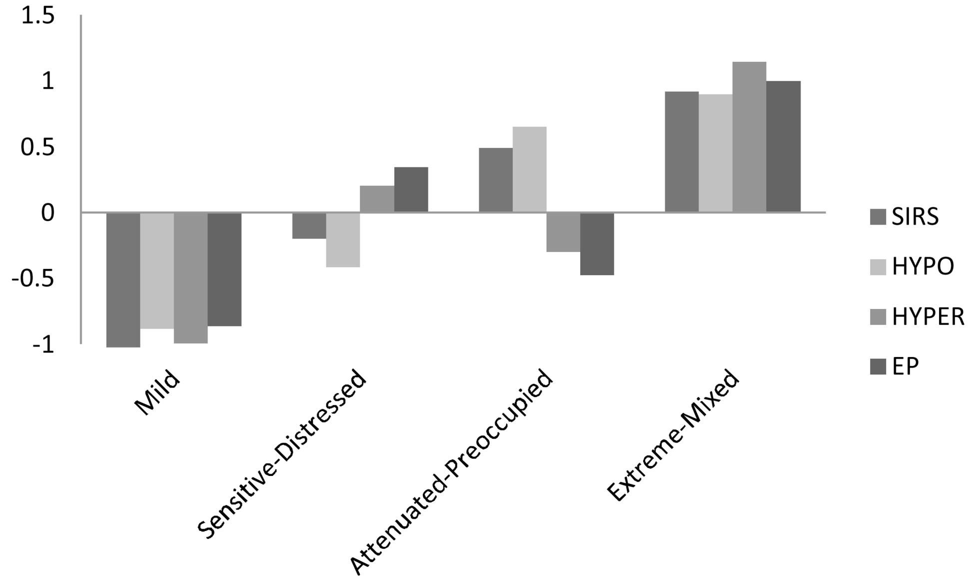

Figure 2. LPTA 4 Profile Solution with Covariates

Table 1

Child and Family Characteristics

	Time 1 Data (N=1294)	Time 2 Data (N=884)
Current ASD Diagnosis (allowed to select more than one)		
Autism/Autistic Disorder (%)	62.9	60.4
Asperger's Disorder (%)	22.1	23.1
PDD-NOS (%)	24.5	25.6
Child's Gender		
Male (%)	82.2	82.8
SRS/P Total Score (SD)	(N=1230)	(N=852)
	107.0 (27.3)	106.4 (27.3)
Chronological Age (SD) months	92.3 (32.6)	104.5 (32.6)
IQ Proxy (SD)	(N=1112)	(N=760)
	81.3 (27.7)	83.3 (27.3)
Mother's College Education (%)	(N=1286)	(N=878)
Partial High School or Lower	0.8	0.5
High School or GED	15.5	12.7
Associates Degree/Partial College	29.0	26.8
Bachelor or Master Degree	50.0	54.6
Advanced Degree such as doctorate	4.1	4.8
Annual Household Income (%)	(N=1209)	(N=813)
Less than $20,000	8.3	6.8
$20,000 to $39,999	17.2	17.1
$40,000 to $59,999	19.3	17.1
$60,000 to $79,999	16.9	16.6
$80,000 to $99,999	14.3	15.4
$100,000 or more	24.0	27.1
Race/Ethnicity (allowed more than one) (%)	(N=1294)	(N=884)
African-American	5.0	5.0
American Indian/Alaskan Native	3.5	3.4
Asian	3.9	4.5
Native Hawaiian/Pacific Islander	0.3	0.3
Other	3.4	2.7
White	93.0	93.0
Hispanic or Latino Origin	9.9	9.2

Table 2

Latent Profile Analysis Fit Statistics Using Cross-Sectional Data

Fit Stats	# of Profiles	AIC	BIC	Entropy	LMR	BLRT
Time 1 LPA (N=1294)						
	3	11924.21	12017.19	0.79	449.73***	-61775.24***
	4	11626.03	11744.84	0.79	299.81**	-5944.10**
	5	11445.57	11590.20	0.78	185.29	-5790.02
		AIC	BIC	Entropy	LMR	BLRT
Time 2 LPA (N=884)						
	3	8117.58	8203.70	0.78	304.10	-4197.32
	4	7922.78	8032.83	0.82	198.93***	-4040.79***
	5	7717.27	7851.23	0.82	209.35**	-3938.39**

Notes: AIC= Akaike Information Criterion; BIC=Bayesian information criteria; LMR=Lo Mendell Rubin; BLRT=bootstrapped likelihood ratio test.

* p-value= >.05,

** >.01,

*** .001

Table 3

Latent Profile Transition Analysis Fit Statistics

Fit Stats	# of Profiles	AIC	BIC	Entropy
LPTA (N=1294)				
	3	19300.916	19445.549	.818
	4	18494.843	18696.297	.855
	5	18055.158	18323.764	0.827
		AIC	BIC	Entropy
LPTA with Covariates (N=1058)				
	4	16919.813	17222.625	0.883

Notes: AIC= Akaike Information Criterion; BIC=Bayesian information criteria.

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Table 4

Characteristics of Participants in Four Stable Sensory Subtypes

	Mild	Sensitive-Distressed	Attenuated-Preoccupied	Extreme-Mixed
Subtype Sample	308 (29%)	291 (28%)	179 (17%)	182 (17%)
Gender (% Males)	79.2	83.0	80.0	82.0
Age/months (SD)	91.0 (34.1)	98.1 (30.4)	79.4 (29.0)	91.1 (30.7)
SRS Total (SD)	83.9 (21.4)	104.5 (19.8)	119.2 (19.5)	134.3 (20.1)
IQ Proxy	83.1 (20.7)	90.7 (24.7)	55.4 (21.0)	83.8 (31.9)
HH Income	63,050	60,820	47,600	40,110
Mother's College Education (%)	67.2	59.5	49.7	41.8

Table 5

Characteristics of Participants that Transition Between Data Time Points

		Time 2			
		Mild Subtype	Sensitive-Distressed Subtype	Attenuated-Preoccupied Subtype	Extreme-Mixed Subtype
Time 1	Mild Subtype		(N=0)	(N=4; 0.4%) Gender (%male)= 100 Age/months (SD)=49.2 (13.4) SRS Total (SD)= 65.3 (13.2) IQ Proxy (SD)=49.5 (10.4) HH Income=40,000 Mother's College=50%	(N=0)
	Sensitive-Distressed Subtype	(N=49; 5.0%) Gender (%male)= 100 Age/months (SD)=109.6 (27.2) SRS Total (SD)=93.8 (21.4) IQ Proxy (SD)= 101.0 (23.0) HH Income=44,080 Mother's College=56%		(N=0)	(N=1; 0.1%) Gender (%male)= 100 Age/months=95.9 SRS Total=51 IQ Proxy=34.4 HH Income= 100,000 Mother's College=100%
	Attenuated-Preoccupied Subtype	(N=5; 0.5%) Gender (%male)= 100 Age/months (SD)=90.2 (13.3) SRS Total (SD)=138.0 (15.2) IQ Proxy (SD)=112.7 (21.0) HH Income=44,000 Mother's College= 60%	(N=0)		(N=0)
	Extreme-Mixed Subtype	(N=1; 0.1%) Gender (%male)= 100 Age/months= 113.9 SRS Total=142 IQ Proxy=131.7 HH Income=20,000 Mother's College=0%	(N=25; 2.0%) Gender (% male)=72 Age/months (SD)=99.4 (30.7) SRS Total (SD)=127.1 (16.4) IQ Proxy (SD)=98.4 (51.2) HH Income=35,200 Mother's College=40%	(N=13; 1.0%) Gender (% male)=92 Age/months (SD)=74.0 (26.7) SRS Total (SD)=111.3 (15.0) IQ Proxy (SD)=55.1 (19.5) HH Income=23,080 Mother's College=23.1%	