Sensory Integration and Praxis Patterns in Children With Autism

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MeSH TERMS
- apraxias
- child development disorders, pervasive
- imitative behavior
- sensation disorders
- social participation

OBJECTIVE. We sought to characterize sensory integration (SI) and praxis patterns of children with autism spectrum disorder (ASD) and discern whether these patterns relate to social participation.

METHOD. We extracted Sensory Integration and Praxis Tests (SIPT) and Sensory Processing Measure (SPM) scores from clinical records of children with ASD ages 4–11 yr ($N = 89$) and used SIPT and SPM standard scores to describe SI and praxis patterns. Correlation coefficients were generated to discern relationships among SI and praxis scores and these scores' associations with SPM Social Participation scores.

RESULTS. Children with ASD showed relative strengths in visual praxis. Marked difficulties were evident in imitation praxis, vestibular bilateral integration, somatosensory perception, and sensory reactivity. SPM Social Participation scores were inversely associated with areas of deficit on SIPT measures.

CONCLUSION. Children with ASD characteristically display strengths in visuopraxis and difficulties with somatopraxis and vestibular functions, which appear to greatly affect participation.

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Estimated prevalence rates of sensory processing problems among children with autism spectrum disorder (ASD) range from approximately 40% to >90% (Baker, Lane, Angley, & Young, 2008; Baranek, David, Poe, Stone, & Watson, 2006; Tomchek & Dunn, 2007). These estimates are primarily based on data from caregiver questionnaires that measure sensory reactivity. The recognized, widespread presence of atypical sensory reactivity among people with ASD recently led to its inclusion as a diagnostic feature of ASD in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; American Psychiatric Association, 2013) under the criterion of "restricted, repetitive patterns of behavior, interests, or activities" (p. 50).

Atypical sensory reactivity (usually called *sensory modulation* or *sensory responsiveness* in the occupational therapy literature) has been linked to regulatory functions such as arousal, attention, affect, and activity level and may result in extreme behavioral differences that interfere with social participation (Baranek, 2002; Ben-Sasson, Carter, & Briggs-Gowan, 2009; Ben-Sasson et al., 2007; Liss, Saulnier, Fein, & Kinsbourne, 2006; Reynolds, Millette, & Devine, 2012; Reynolds, Thacker, & Lane, 2012). Some researchers have reported positive associations between hyporeactivity and social communication symptom severity (Watson, Baranek, Roberts, David, & Perryman, 2010), whereas others have found that child hyperreactivity is likely to negatively affect family life and social adaptive behaviors of school-age children (Ben-Sasson et al., 2009).

Sensory reactivity is only one of several sensory integration (SI)-related patterns of functioning known to affect children who have learning and

behavioral challenges. These patterns emerged in past factor analytic studies using the Sensory Integration and Praxis Tests (SIPT; Ayres, 1989) with diverse samples of children (e.g., Ayres, 1989; Mailloux et al., 2011; Mulligan, 1998). *Visuopraxis* is a pattern that refers to the ability to skillfully plan actions that are heavily dependent on vision. This pattern is measured by tests of visual perception and visual construction (Ayres, 1963, 1965, 1966a, 1966b, 1969, 1972, 1977, 1989; Mailloux et al., 2011; Mulligan, 1998). Another pattern, *somatopraxis,* reflects the ability to organize actions in relation to one's own body. This pattern is measured by tasks requiring imitation of body positions and movement sequences and is strongly associated with measures of somatosensory perception (Ayres, 1965, 1966a, 1966b, 1969, 1971, 1972, 1977, 1989). *Praxis on verbal command* refers to planning of action while following verbal instructions (Ayres, 1969, 1972, 1977, 1989; Mulligan, 1998). The *vestibular–postural–bilateral integration and sequencing pattern* refers to smoothly coordinated head, neck, and eye movements in concert with postural and bilateral control (Ayres, 1965, 1966b, 1969, 1971, 1972, 1977, 1989; Mailloux et al., 2011; Mulligan, 1998).

It is plausible that, in addition to sensory reactivity, SI patterns such as visuopraxis, somatopraxis, and vestibular–postural–bilateral functions may also have an effect on the social participation of children with autism. Although dyspraxia is not currently recognized as a diagnostic feature of ASD, a growing body of evidence indicates that substantial difficulties with praxis are common among people with ASD and may even be a core feature of autism (Dowell, Mahone, & Mostofsky, 2009; MacNeil & Mostofsky, 2012). Motor and praxis concerns have been reported for children with ASD based on scores from a variety of motor tests and movement observations (Henderson & Sugden, 1992; Henderson, Sugden, & Barnett, 2007; Manjiviona & Prior, 1995; McDuffie et al., 2007; Minshew, Sung, Jones, & Furman, 2004; Mostofsky et al., 2006; Rogers & Williams, 2006; Siaperas et al., 2011; Smith & Bryson, 2007).

Dziuk et al. (2007) and Mostofsky et al. (2006) found deficits among children with ASD in ability to produce meaningful and meaningless gestures on command, imitate demonstrated gestures without objects, and imitate gestures involving real or imaginary tool use. These praxis abilities require the child to interpret sensory information and then formulate internal action models. Ayres and Cermak (2011) suggested that somatodyspraxia interferes with initiation, planning, sequencing, and building repertoires of action plans, all of which are essential in accomplishing multistep daily routines and building a foundation for imitation and social skills. Moreover, praxis abilities may be associated with social and communicative functions of people with ASD (Mostofsky & Ewen, 2011). Therefore, it is reasonable to expect that difficulties with praxis, or with the perceptual functions that support praxis, will interfere with the social participation of children with ASD.

Although vestibular bilateral functions are seldom studied in children with ASD, evidence suggests that prolonged head lag in infancy, an early manifestation of delayed postural control development, is predictive of later diagnosis of ASD (Flanagan, Landa, Bhat, & Bauman, 2012). Limited research on groups of older children with ASD (Jansiewicz et al., 2006; Minshew et al., 2004) described postural–ocular control difficulties such as ability to orient, shift, and organize visual gaze; sit still and upright while working; and use tools and writing implements, which requires a stable postural base of support (Ayres, 2005). Such difficulties with postural control may interfere with the child's ability to participate in activities with the same degree of efficiency and skill in movement that is evident in most children.

We designed this study to contribute to the growing pool of knowledge on how SI and praxis may relate to social participation of children with ASD. Therefore, we sought to answer two specific research questions: (1) What are the characteristic SI and praxis features and patterns of children with ASD? and (2) What are the relationships between these SI and praxis features and patterns and social participation in children with ASD?

Method

Research Design

This retrospective study examined existing data on children with ASD ages 4–11 yr (mean age, 7 yr) who were evaluated as part of a comprehensive occupational therapy assessment. We first reviewed records of 421 children to identify those with ASD, of whom we found 141. We then examined the records of the 141 children with ASD to identify those who had completed at least 11 of the 17 tests of the SIPT ($N =$ 89, 63%). Demographic data for the 141 children with ASD who could take the SIPT ($N = 89$) and those who could not take the SIPT ($N = 52$) are summarized in Table 1 and indicate similarity between groups on age, gender distribution, ethnicity, and diagnostic categories.

We used the SIPT test scores of these 89 children to describe characteristic patterns of SI and praxis functioning of children with ASD. Of these 89 children, 75 were in the age range of the SIPT normative data. The performance of 14 children ages 9–11 yr was scored using

Table 1. Demographics of Participants ($N = 141$) With and Without Sensory Integration and Praxis Tests Scores

Characteristic	SIPT ($N = 89$)	No SIPT ($N = 52$)
Age, yr (mean ± standard deviation)	7 ± 2	7 ± 2
Gender, *n* (%)		
Male	78 (88)	41 (79)
Female	11 (12)	11 (21)
Ethnicity, *n* (%)		
White	67 (75)	41 (79)
Hispanic	11 (13)	3 (6)
Asian	10 (11)	7 (13)
African-American	1 (1)	1 (2)
Diagnosis, *n* (%)		
Asperger syndrome	8 (9)	3 (6)
Autism	74 (83)	46 (88)
PDD/PDD–NOS	7 (8)	3 (6)

Note. PDD = pervasive developmental disorder; PDD–NOS = pervasive developmental disorder–not otherwise specified; SIPT = Sensory Integration and Praxis Tests.

SIPT normative data for children age 8 yr, 11 mo, the oldest age group on which the SIPT is standardized. Records for a subset of these 89 children ($N = 48$) also contained standard scores for the Sensory Processing Measure (SPM) Home Form (Parham & Ecker, 2007). In the records of the 48 children with SPM Home Form scores, 25 also contained scores for the SPM Main Classroom Form (Miller Kuhaneck, Henry, & Glennon, 2007). We used the SPM Home and Main Classroom scores to further describe SI patterns and their relationship to social participation. We obtained ethical approval for this study from the institutional review board, Office of Protection of Research Subjects, at the University of Southern California, Los Angeles.

Participants

We drew the ASD sample from two private practices in Southern California. Inclusion criteria were children who (1) received an occupational therapy evaluation from 1989 to 2011, (2) were diagnosed with ASD, (3) were between ages 4.0 and 11.0 yr, and (4) completed at least 11 of the 17 SIPT tests. For 60% of the sample the diagnosis was provided by a psychologist, physician, neuropsychologist, or neurologist. For 40% of the sample, the professional who provided the diagnosis was not identified. The ASD diagnoses included Asperger syndrome, autism (including high-functioning autism), pervasive developmental disorder (PDD), and PDD–not otherwise specified (PDD–NOS). Attention deficit disorder was reported by 16.8% of families of children with autism. Children with additional diagnoses of seizure disorder, Fragile X syndrome, cerebral palsy, or mental retardation were excluded from the study. Although measures of intelligence were not available in the majority of records, it is reasonable to assume that children who were able to complete the SIPT fell in the typical range of cognitive functioning because performance on this test requires the child to conceptually understand and comply with standardized procedures involving novel tasks.

Measures

The SIPT are a series of 17 tests, standardized on 1,997 children ages 4 yr to 8 yr, 11 mo, designed to assess visual and tactile perception, visual–motor skills, two- and three-dimensional construction, vestibular–proprioceptive functions, bilateral motor skills, and praxis (Ayres, 1989). Each test has high interrater reliability ($r \geq .90$) and discriminates between typical and atypical samples ($p < .01$; Ayres, 1989). Content validity and construct validity have been established. Each test of the SIPT is administered using visual demonstration in addition to standardized verbal instructions with the exception of Praxis on Verbal Command, which is solely language dependent. A lower SIPT score indicates greater difficulty.

The SPM is a questionnaire completed by parents or teachers that provides standard scores based on a normative sample of 1,051 typically developing children ages 5–12 yr (Parham & Ecker, 2007). SPM scores provide information about the child's sensory reactivity, praxis, and social participation. The Total Sensory scale score is a composite measure of the Visual, Hearing (auditory processing), Touch, Body Awareness (proprioception), and Balance and Motion (vestibular processing) scale scores, which primarily measure sensory reactivity within specific sensory systems. The Total Sensory score also includes items measuring reactivity to taste and smell. The Ideas and Planning score is a measure of praxis. The Social Participation score is a measure of child participation. A higher SPM score indicates greater difficulty. Content and construct validity has been established with strong test–retest reliability ($r > .93$). Scores from the SPM Home Form and Main Classroom Form were analyzed in this study.

Data Analysis

Descriptive statistics were generated for the *z* score of each of the 17 SIPT tests and for the *T* score of each SPM Home and Main Classroom scale. Next, the 17 SIPT scores were collapsed into six SI and praxis functions on the basis of past factor and cluster analyses involving normative and clinical samples (Ayres, 1989; Mailloux et al., 2011; Mulligan, 1998). The six functions are (1) Visual Perception (consisting of tests of motor-free visual perception), (2) Visual Construction (tests of visual–motor

performance, including two- and three-dimensional construction), (3) Imitation Praxis (tests requiring imitation of body or orofacial position and movement), (4) Vestibular Bilateral Integration and Sequencing (tests of vestibular functions, including balance and bilateral motor performance), (5) Somatosensory Perception (tests of tactile and kinesthetic perception), and (6) Praxis on Verbal Command (test of praxis based on unfamiliar two-step verbal instructions—the only SIPT test dependent on language comprehension). A score for each function was created by computing the mean of the *z* scores of the constituent tests.

Mean SIPT *z* scores, SIPT SI and praxis function scores, and SPM *T* scores were scrutinized to determine the extent to which each SI and praxis measure is characteristic of children with ASD, as indicated by distance of the sample mean from the normative mean. Scores greater than 1 standard deviation from the normative mean are considered to be clinically meaningful. On the SIPT, *z* scores ≤–1.0 indicate areas of concern. On the SPM, *T* scores ≥60 indicate areas of concern. To determine the associations among SI, praxis, and social participation measures, a correlation matrix was generated using Pearson correlation procedures. Variables analyzed in the correlation matrix were the six SI and praxis function scores and the SPM Total Sensory, Ideas and Planning, and Social Participation scores for both Home and Main Classroom forms.

Results

Characteristic Sensory Integration and Praxis Patterns

Table 2 depicts the mean *z* scores of children with ASD on SIPT. Scores for the Visual Perception and Visual Construction functions were the only ones within normal limits (i.e., >–1.0). Of the SIPT tests that measure these functions, the only mean *z* score <–1.0 was on the Motor Accuracy test. Scores for Somatosensory Perception and Vestibular Bilateral Integration and Sequencing functions were ∼–1.2. The Praxis on Verbal Command function was an area of greater impairment, with a score of –1.4, but the score reflecting the area of greatest difficulty was Imitation Praxis (–1.5).

Table 3 depicts the mean *T* scores of children with ASD on the SPM Home and Main Classroom forms. Scores of 0–59 indicate typical function; 60–69, probable dysfunction; and 70–80, definite dysfunction. The mean scores on the SPM Home were all well above 60 (T = 65–70). The area of greatest difficulty was Social Participation, followed by Total Sensory, Hearing, and Planning and Ideas (praxis) scales. Most of the mean scores on the SPM Main Classroom were >60 (T = 59–67), with three borderline mean scores at 59 or 60. On the Main Classroom form, the area of greatest difficulty was Social Participation, followed by Planning and Ideas and Total Sensory scales.

Table 2. SIPT *z* Score Means and Standard Deviations

SIPT Tests by Group	*N*	*M*	*SD*
Motor-Free Visual Perception Group	88	−0.7	1.0
1. Space Visualization	88	−0.7	1.0
2. Figure Ground Perception	87	−0.6	1.2
Visual Praxis Group	89	−0.8	1.0
3. Design Copying	86	−0.9	1.5
4. Constructional Praxis	88	−0.6	1.1
5. Motor Accuracy	88	−1.3	1.2
Imitation Praxis	89	−1.5	1.1
6. Postural Praxis	88	−1.4	1.4
7. Oral Praxis	89	−1.8	1.0
Vestibular Bilateral Integration and Sequencing	89	−1.2	0.9
8. Postrotary Nystagmus	87	−1.0	1.2
9. Standing and Walking Balance	89	−2.0	1.1
10. Sequencing Praxis	89	−1.2	1.3
11. Bilateral Motor Coordination	89	0.8	1.0
Somatosensory: Tactile and Kinesthesia	89	1.2	1.0
12. Manual Form Perception	88	−0.9	1.3
13. Kinesthesia	83	−1.3	1.3
14. Finger Identification	86	−1.1	1.4
15. Graphesthesia	86	−1.7	1.4
16. Localization of Tactile Stimuli	84	−1.4	1.4
Praxis on Verbal Command			
17. Praxis on Verbal Command	89	−1.4	1.5

Note. *M* = mean; *SD* = standard deviation; SIPT = Sensory Integration and Praxis Tests.

Relationships Between Social Participation and Sensory Integration and Praxis Functions

Table 4 presents the correlations among the six SI and praxis functions measured by the SIPT and the three

Table 3. SPM Home and Main Classroom Form *T*-Score Means and Standard Deviations

	Home Form			Main Classroom Form		
SPM Scale	*N*	*M*	*SD*	*N*	*M*	*SD*
Social Participation	48	70	7.2	26	67	8.0
Planning and Ideas	46	68	8.6	26	63	6.8
Total Sensory	46	69	7.1	26	62	7.2
Visual	48	67	7.9	26	59	7.8
Hearing	48	68	8.8	26	61	10.0
Touch	48	66	9.1	26	60	9.2
Proprioception	47	67	7.5	26	60	7.9
Balance	46	65	10.2	26	61	8.1

Note. *T* score: 0–59, typical function; 60–69, probable dysfunction; 70–80, definite dysfunction. *M* = mean; *SD* = standard deviation; SPM = Sensory Processing Measure.

Table 4. Correlations Among Sensory Integration and Praxis Tests and Sensory Processing Measure Home and Main Classroom Form Scores

Test	1	2	3	4	5	6	7	8	9	10	11	12
1. SIPT Visual Perception	—											
2. SIPT Visual Construction	.50***	—										
3. SIPT Imitation Praxis	.36***	.43***	—									
4. SIPT Vestibular Bilateral Integration and Sequencing	.36***	.61***	.51***	—								
5. SIPT Somatosensory Perception	.50***	.54***	.48***	.56***	—							
6. SIPT Praxis on Verbal Command	.36***	.55***	.51***	.54***	.51***	—						
7. SPM–H Social Participation	−.10	−.20	−.48**	−.35*	−.25*	−.32	—					
8. SPM–H Planning and Ideas	−.09	−.22	−.21	−.10	−.09	−.10	.41**	—				
9. SPM–H Total Sensory	.10	−.04	−.10	.02	.02	-.05	.52***	.67***	—			
10. SPM–C Social Participation	−.19	−.38	−.65***	−.54**	−.44*	−.33	.40	−.11	−.09	—		
11. SPM–C Planning and Ideas	−.26	−.21	−.47*	−.24	−.35	−.37	−.03	.17	.17	.48*	—	
12. SPM–C Total Sensory	−.07	−.08	−.56**	−.28	−.37	−.34	.11	.10	.14	.49*	.68***	—

Note. SPM–C = Sensory Processing Measure Main Classroom Form; SPM–H = Sensory Processing Measure Home Form; SIPT = Sensory Integration and Praxis Tests. *N*s for SIPT functions = 83–89; *N*s for SPM–H = 46–48; *N* for SPM–C = 26.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

SPM scales (Social Participation, Ideas and Planning, and Total Sensory) for the Home and Main Classroom forms. SIPT functions that correlated most highly with Social Participation in the home were Imitation Praxis ($r = -.48$, $p < .001$) and Vestibular Bilateral Integration and Sequencing ($r = -.35$, $p < .05$). Praxis on Verbal Command also had a significant correlation with Social Participation at home in the low moderate range ($r = -.32$, $p < .05$). With regard to Social Participation in the classroom, the strongest SIPT correlations were with Imitation Praxis ($r = -.65$, $p < .001$) and Vestibular Bilateral Integration and Sequencing ($r = -.54$, $p < .01$). Somatosensory Perception also correlated significantly with Social Participation at school ($r = -.44$, $p < .05$).

As expected, Imitation Praxis showed significant correlations with SPM Main Classroom Planning and Ideas ($r = -.47$, $p < .05$) and Total Sensory ($r = -.56$, $p < .01$) scores. However, it was surprising that Imitation Praxis did not significantly correlate with these areas on the SPM Home. The mean scores for Visual Perception and Visual Construction did not correlate significantly with scores on either of the SPM forms.

The SI and praxis functions on the SIPT were significantly correlated with each other ($r = .36$ to $.61$, $p < .01$). The SPM Home scores for Social Participation, Planning and Ideas, and Total Sensory scales correlated with each other ($r = .41$ to $.67$, $p < .001$), as did the same scales on the SPM Main Classroom ($r = .47$ to $.68$, $p < .001$). The correlation between the Social Participation scales of the SPM Home and Main Classroom forms was moderate ($r = .40$) but not statistically significant. The remaining intercorrelations among the SPM Home and Main Classroom scores were close to zero ($r = .03$ to $.17$).

Discussion

The results of this study show that children with ASD characteristically displayed difficulties with imitation praxis, vestibular bilateral functions, somatosensory perception, and sensory reactivity. The areas of greatest strength are visual perception and visual construction. In contrast, imitation praxis is severely affected. Behaviors indicating praxis problems and difficulty with sensory reactivity across multiple sensory systems are evident in the contexts of both home and school. Social participation at school in particular is strongly associated with imitation praxis and vestibular bilateral functions. Similarly, social participation at home is primarily associated with imitation praxis and, to a lesser degree, vestibular bilateral functions.

Prior research has shown that SIPT Visual Perception and Visual Construction scores tend to be highly correlated and often load together on a factor that Ayres (1989) termed *visuopraxis*. Likewise, Somatosensory Perception, Imitation Praxis, Praxis on Verbal Command, and Vestibular Bilateral Integration and Sequencing scores tend to be highly correlated and load together on a factor that Ayres (1989) termed *somatopraxis*. Our study shows that children with ASD have strengths in visuopraxis and major deficits in somatopraxis.

To date, much research has shown that sensory reactivity is a major issue in children with ASD. In contrast, very little research has examined somatopraxis of these children. Results of the current study indicate that somatopraxis may be an area of difficulty that is as prevalent as sensory reactivity problems for this population. Moreover, findings of this study suggest that social participation is more strongly associated with somatopraxis than with sensory reactivity.

The lowest mean SIPT score was on the Standing and Walking Balance test, reflecting vestibular-related difficulties with postural control. Vestibular-related functions are important considerations during the evaluation and intervention of children with ASD.

Because of the language processing requirement for the Praxis on Verbal Command test, we expected children with ASD to have difficulty with this test. Because of the importance of language during social interactions, a surprising finding was that Praxis on Verbal Command showed lower correlations with Social Participation than Imitation Praxis.

The lack of significant correlations between the SPM Home and Main Classroom forms is consistent with findings reported in the SPM Home Form (Parham & Ecker, 2007) and may be explained by the discrepancy between adult expectations and daily routines at home versus at school. The degree of adult support and varying contextual demands are important considerations with people with ASD.

In summary, comprehensive evaluations of sensory reactivity, sensory perception, and praxis allow occupational therapy practitioners to understand critical abilities linked to adaptation and social skills in ASD. Children with ASD show relative strengths in visual praxis and deficits in somatopraxis; vestibular-related functions, including balance; and sensory reactivity. Standardized measures of SI and praxis functions allow practitioners to ascertain difficulties that are often not overtly apparent but have a great impact on the way in which people with ASD choose to engage with people and objects in their environment.

Limitations and Future Research

This study is based on an analysis of existing data in clinical records. Although most of the children were diagnosed by medical professionals, independent assessments to verify the diagnosis of ASD and measures of cognitive abilities were not available. The SPM Home and Main Classroom forms were available only for a subset of children with ASD who had completed the SIPT, resulting in smaller samples of children with data from these questionnaires. Another limitation was the inclusion of 14 children ages 9–11 yr, whose performance was scored using SIPT normative data for children ages 8 yr, 11 mo, the oldest age group on which the SIPT is standardized. For these older children, the use of normative data from younger children may have led us to underestimate the severity of SI and praxis difficulties experienced by children with ASD.

Additional standardized performance assessments are needed to measure SI and praxis in people with more severe expressions of ASD and in older and younger age groups than we studied here so that future research can examine whether SI and praxis are associated with social participation in these groups. Larger sample sizes of people with ASD who also have SPM and SIPT data are needed to conduct factor analyses to further clarify patterns of SI and praxis deficits in autism. Studies investigating the subjective experiences of people with ASD and their caregivers would be useful to better understand the effects of various types of SI and praxis deficits on social participation. Future studies may provide increased understanding of the nature of SI and praxis and their impact on engagement in occupations as a means toward health, well-being, and participation.

Implications for Occupational Therapy Practice

The results of this study have the following implications for occupational therapy practice:

- A thorough SI assessment must address perception and praxis in addition to sensory reactivity to fully inform practice and provide a deeper understanding of the SI factors that affect social participation of children with ASD.
- Assessment tools commonly used by occupational therapists to evaluate children with ASD, such as motor skill tests and sensory history questionnaires, may not adequately capture critical information related to SI and praxis; thus, issues that strongly influence child participation may be left untreated.
- Identification of SI and praxis deficits in children with ASD can inform the use of safe and effective intervention strategies that have the potential to expand children's social participation. ▲

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