Sensory Processing, School Performance, and Adaptive Behavior of Young School-Age Children with Fetal Alcohol Spectrum Disorders

Tracy Jirikowic, PhD, OTR/L
Heather Carmichael Olson, PhD
Deborah Kartin, PT, PhD

ABSTRACT. This study described sensory processing behaviors and sensory-motor abilities in children with fetal alcohol spectrum disorders (FASD) and explored their relationship to home and school function.

Tracy Jirikowic is an occupational therapist in the University of Washington Fetal Alcohol Syndrome Diagnostic and Prevention Network (FAS DPN) and a postdoctoral research fellow in the Department of Psychosocial and Community Health, School of Nursing, Seattle, WA.

Heather Carmichael Olson is a psychologist in the University of Washington FAS DPN and a senior lecturer in the Division of Child Psychiatry, Department of Psychiatry and Behavioral Sciences, University of Washington School of Medicine, Seattle, WA.

Deborah Kartin is an associate professor in the Department of Rehabilitation Medicine, Division of Physical Therapy, University of Washington School of Medicine, Seattle, WA.

Address correspondence to: Tracy Jirikowic, Department of Rehabilitation Medicine, Division of Occupational Therapy, University of Washington School of Medicine, Box 356490, Seattle, WA 98105 (e-mail: tracyj@u.washington.edu).

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A clinic-referred sample of 25 children with FASD, ages 5 to 8 years, was compared with 26 children with typical development, balanced for age, gender, and race/ethnicity, on standardized tests examining sensory processing, sensory-motor performance, school performance, and adaptive behavior. Children with FASD scored significantly more poorly on sensory processing, sensory-motor, adaptive, and academic achievement measures, and demonstrated more problem behaviors at home and school. Correlations were significant between measures of sensory processing and sensory-motor performance, adaptive behavior, and some aspects of academic performance. Sensory processing and related foundational sensory-motor impairments should be considered when determining the developmental needs of children with FASD. These impairments may co-occur with and contribute, at least in part, to decreased adaptive and school function.

KEYWORDS. Sensory integration, sensory-motor development, fetal alcohol syndrome, occupational therapy, adaptive function

Alcohol is a neurobehavioral teratogen that can disrupt fetal development, especially early brain development (Stratton, Howe, & Battaglia, 1996). Prenatal alcohol exposure may result in fetal alcohol syndrome (FAS) or a continuum of other physical, neurological, and behavioral effects that are now referred to under the umbrella term of fetal alcohol spectrum disorders (FASD) (Bertrand et al., 2004). The enduring effects of brain damage associated with prenatal alcohol exposure have been described in a growing body of research. These include cognitive, motor, executive function, learning, and attention deficits (Mattson & Riley, 1998; Riley & McGee, 2005). Individuals affected by prenatal alcohol exposure also demonstrate a multitude of lifelong functional problems (e.g., school failure, mental health problems), also known as "secondary disabilities," which have been attributed to underlying central nervous system (CNS) dysfunction that is either not recognized, or is misunderstood or ignored (Streissguth et al., 2004).

Sensory processing is one area of neurobehavioral function not yet adequately documented in research investigations of children with FASD. Sensory processing refers to the neurological process of receiving, modulating, and integrating sensation and the subsequent organization of sensation for use (Schaaf & Miller, 2005). Theoretically, efficient sensory processing supports function by facilitating "adaptive responses" to the changing sensory demands of the environment (Ayres, 1972). Hence, from a sensory integration (SI) framework, sensory processing is considered an important substrate for higher-level learning, adaptive behavior, and social-cognitive functioning (Ayres, 1972; Parham & Mailloux, 2005).

Individuals with sensory processing disorders (SPDs) inadequately or unreliably interpret and organize sensory information from the body or environment (Lane, Miller, & Hanft, 2000). This disruption may result in an array of behavioral symptoms or patterns that reflect the individual's underlying neurological disorganization or poor modulation (e.g., hyper- or hyposensitivity to stimuli) in response to sensation (Dunn, 1997; Schaaf & Miller, 2005). The behavioral and functional manifestations commonly associated with SPD include poor behavior regulation (e.g., hyperactivity, withdrawal, emotional reactivity) and/or difficulty planning and carrying out motor actions (e.g., clumsiness) (Lane et al., 2000). These difficulties may result in challenges meeting appropriate developmental expectations and achieving success at home, at school, and in the community.

Clinically, many symptoms of SPD (e.g., clumsiness, inattention, hypersensitivity to stimuli, emotional reactivity) are reported anecdotally among children with FASD. Yet, Morse, Miller, and Cermak (1995) provided the only published research evidence known to date that examined sensory processing behaviors in this population. They compared a sample of 90 children with diagnoses falling under the umbrella term of FASD with 90 controls, ranging from 2 to 19 years of age, using a nonstandardized sensory history questionnaire. Behaviors related to SPD occurred two to six times more often among the group of children with FASD. Specifically, domains of visual-spatial processing, auditory processing, and tactile processing were found to be problematic (Morse & Cermak, 1994). These findings provided preliminary evidence of SPD in this population; however, findings were limited by reliance on questionnaire measures that were under development, a sample with a wide age range, and subjects diagnosed using methods that were not as systematic and clearly defined as those currently in use.

Furthermore, although a range of compromised sensory-motor abilities (e.g., decreased balance and coordination, poor fine-motor skills) have been described in children affected by prenatal alcohol exposure (Mattson & Riley, 1998; Osborn, Harris, & Weinberg, 1993), there has been little systematic investigation of sensory-motor performance in children with FASD from a clinical perspective using an SI theoretical framework. Neither has there been consideration of the relationship between foundational sensory processing and sensory-motor abilities and the array of social, emotional, school, and adaptive difficulties that are often reported as problematic in this population (Roebuck, Mattson, & Riley, 1999; Whaley, O'Connor, & Gunderson, 2001).

This study describes sensory processing behaviors and related sensory-motor performance of a clinical sample of young school-age children systematically diagnosed with FASD in comparison to peers with typical development (TD). Indicators of home and school performance were examined to concurrently describe daily life skills within these important contexts and explore the purported theoretical links between sensory processing, foundational sensory-motor abilities, and daily function. Specifically, the following research hypotheses were addressed:

- Children with FASD will perform more poorly than children with TD on measures of sensory processing behaviors, sensory-motor performance, adaptive behavior, academic achievement, and teacher-rated classroom behaviors.
- Measures of sensory processing and sensory-motor performance will be significantly correlated with adaptive behavior, academic achievement, and teacher-rated classroom behaviors.

METHODS

Participants

This study was approved by the University of Washington Human Subjects Division. Children with FASD were selected through a clinical registry that included more than 1,500 children and adults systematically diagnosed with FASD from the University of Washington Fetal Alcohol Syndrome Diagnostic and Prevention Network. FASD diagnoses were derived by an interdisciplinary team using the 4-Digit Diagnostic Code (Astley & Clarren, 2000; Clarren, Carmichael Olson, Clarren, & Astley, 2000). The four digits in the code reflect the magnitude of expression of the four key diagnostic features of FASD in the following order: (a) growth deficiency, (b) a unique cluster of minor facial anomalies, (c) evidence of CNS damage/dysfunction, and (d) prenatal alcohol exposure. The magnitude of expression of each feature is ranked independently on a 4-point Likert scale, with "1" reflecting complete absence of the FAS feature and "4" reflecting strong and "classic" presence of the FAS feature. Each Likert scale is specifically case defined. Diagnoses of all participants were updated and coded according to criteria from the 2004 version of the 4-Digit Diagnostic Code (Astley, 2004).

Children with FASD were eligible if they (a) were between 5 and 8 years of age; (b) lived within a 125-mile radius of Seattle; and (c) had a 4-Digit Diagnostic Code of Neurobehavioral Disorder (alcohol exposed), Static Encephalopathy (alcohol exposed), Partial FAS (alcohol exposed), or Full FAS (with or without confirmed alcohol exposure). To bridge the gap between diagnostic terminology, the first two diagnostic classifications are comparable to what Stratton et al. (1996) referred to as "alcohol-related neurodevelopmental disorder" (ARND). To decrease the possible confounding effects of a new or unstable caregiving environment on performance or behavior, children with FASD were excluded if they had resided in their current home or foster placement for less than 1 year. Children with FASD who had a severe physical or neurological disability (e.g., cerebral palsy, spina bifida) or intellectual disability (e.g., IQ standard score <60 or descriptive evidence of severe mental retardation) were excluded to reduce the confounding effects of severe motor and/or intellectual impairments on performance.

Twenty-five children with FASD and 26 children with TD participated in the study. From the initial population of 1,500 individuals, 73 children with FASD were considered eligible and invited to participate. Of the 73 invited, 25 families (34%) agreed to participate. These 25 children were considered representative of the 73 invited because no statistically significant differences were found on key sociodemographic variables (i.e., gender, race/ethnicity, spectrum of diagnoses).

For the comparison group, recruitment letters were sent to 300 caregivers of children with presumed TD in grades kindergarten through 2, attending participating local public schools and community after-school programs. Inclusion/exclusion criteria were used to help achieve a group comparable in age, gender, and race/ethnicity to the FASD group. Because of low response rates (9%), the eligible children of all caregivers that responded were enrolled. All children in the comparison group were enrolled in regular education programs and received no special education services. Comparison group participants were not formally screened for prenatal alcohol exposure because of confidentiality restrictions imposed by the educational institutions that agreed to participate in subject recruitment. It was assumed that the risk of adverse outcomes because of prenatal alcohol exposure would be low since only children without any special education services (and so presumed TD) were eligible to enroll in the comparison group.

Group characteristics are presented in Table 1. The groups were comparable on age, gender, and race/ethnicity with similar distributions of White and non-White participants. The groups differed significantly by grade level. Several children with FASD were still enrolled in preschool or

TABLE 1. Participant Demographic Characteristics as Reported by Primary Caregiver

Variable	Fetal Alcohol Spectrum Disorder ($n = 25$)	Typical Development ($n = 26$)	Test Statistic[a]	p Value
Child gender n (%)				
Male	14 (56%)	14 (54%)	$\chi^2 = 0.18$	.78
Female	11 (44%)	12 (46%)		
Child age				
Mean (SD)	6.5 years (0.88)	6.9 years (0.85)	$t = 1.63$[b]	.11
Lo/hi	5.0–8.0 years	5.3–8.5 years		
Child race/ethnicity n (%)				
White	12 (48%)	13 (50%)	$\chi^2 = 7.31$	.12
Black	3 (12%)	2 (8%)		
Hispanic/Latino	1 (4%)	4 (15%)		
Native American	4 (16%)	0 (0%)		
Other/not reported	5 (20%)	7 (27%)		
Caregivers in household n (%)				
Single caregiver	8 (32%)	3 (12%)	$\chi^2 = 3.21$	.20
Two caregivers	12 (48%)	17 (65%)		
Other/not reported	5 (20%)	6 (23%)		
Family structure n (%)				
Biological parent(s)	2 (8%)	19 (73%)	$\chi^2 = 40.26$	.001
Foster/guardianship	7 (28%)	1 (4%)		
Adoptive	16 (64%)	0 (0%)		
Not reported	0 (0%)	6 (23%)		
Grade n (%)				
Preschool	7 (28%)	0 (0%)	$\chi^2 = 9.06$	.03
Kindergarten	8 (32%)	10 (40%)		
Grade 1	7 (28%)	9 (36%)		
Grade 2	3 (12%)	7 (24%)		

[a] χ^2 analysis.
[b] Independent samples t test.

developmental preschool, whereas all children with TD were enrolled in kindergarten through grade 2. The two groups also differed significantly by household structure, but not by number of caregivers in the household. Most children in the comparison group were living with biological parents, whereas all but two children with FASD were in adoptive, guardianship, or foster placements.

All children with FASD had confirmed alcohol exposure. Sixty percent were exposed to high levels of alcohol (i.e., 4-Digit Diagnostic Code, Alcohol Scale Rank 4, indicating an exposure pattern consistent with the medical literature placing the fetus at high risk). The remainder had evidence only of confirmed prenatal alcohol exposure (i.e., 4-Digit Diagnostic Code, Alcohol Scale Rank 3) (Astley, 2004). Five of the participants were diagnosed with FAS (with confirmed prenatal alcohol exposure), whereas the remaining 20 had diagnoses on the broader fetal alcohol spectrum. Of those without FAS, 3 (12%) had static encephalopathy + alcohol exposure (the equivalent of severe ARND), whereas the remaining 17 (68%) had neurobehavioral disorder + alcohol exposure (the equivalent of mild ARND) (Astley, 2004; Stratton et al., 1996).

Instrumentation

Table 2 presents the standardized tests administered, the test acronyms used in the remainder of this article, and the specific domains assessed by each measure. A brief summary of psychometric properties is also included in Table 2. All measures were standardized and considered psychometrically reliable and valid.

Procedure

After informed consent was obtained, participants were scheduled for a 2- to 3-hour test session at the child's home or school, or at the university child development clinic based on family preference. Each child was administered standardized developmental tests (Table 2) in the same sequence. All but 2 children (both in the group with FASD) completed the testing in one session. Examiners were a pediatric occupational therapist (OT) and physical therapist (PT), each with at least 2 years of clinical experience, who tested a comparable number of children in each group and were unaware of group status. Mean inter-rater agreement on sensory-motor performance-based measures reached or exceeded 85% during training and remained at 87% to 93% when checked with the primary investigator at four random sessions throughout the study. Each child's primary caregiver completed two behavioral checklists (Table 2), and each child's teacher, unaware of the study's focus on children with prenatal alcohol exposure, completed the teacher version of the Social Skills Rating System (SSRS).

Data Analysis

As expected, the two groups differed significantly by IQ [$t(49) = -1.74$, $p = .009$ (two tailed)]; therefore, analysis of covariance with the Test

TABLE 2. Summary and Description of Standardized Assessments

Test	Description	Reliability and Validity
Sensory Processing		
Short Sensory Profile (SSP)[a] (Dunn, 1999)	Caregiver report of sensory processing behaviors. 38-item questionnaire scored on a 5-point Likert scale (1 = "always" to 5 = "never").	Internal consistency for total score (Cronbach's alpha = 0.96) and section scores (Cronbach's alpha = 0.82 to 0.89). Intercorrelations between total score and seven section scores (r= 0.48 to 0.80).
Sensory-Motor Performance		
Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)[b] (Bruininks, 1978)	Survey of general fine-motor and gross-motor skills.	Short form intercorrelations with long form gross-motor, fine-motor, and battery composite scores (r= 0.78, 0.76, and 0.91, respectively). Test–retest reliability (r= 0.86). Standard error of measurement = 4.6.
Quick Neurological Screening Test–II (QNST-II)[b] (Mutti et al., 1998)	Measures of neurological soft signs, including motor coordination, balance, and vestibular function; visual/auditory perceptual skills; motor planning; sequencing; and spatial organization.	Inter-rater reliability (r= 0.69 to 0.71). Test–retest reliability (r= 0.81). Moderate criterion validity with measures of academic achievement, developmental screening, auditory perception, and medical/neurological exams.
Developmental Neuropsychological Examination (NEPSY)[b] Sensorimotor Core (Korkman, Kirk, & Kemp, 1998)	Measures of tactile processing, motor planning and sequencing, visual-motor precision, and coordination.	Test–retest reliability for sensorimotor core (5- to 12-year-olds) (r= 0.79). Average stability coefficient for sensorimotor subtests (r= 0.67). Moderate to high criterion validity correlating significantly with other neuropsychological measures.
Developmental Neuropsychological Examination (NEPSY)[b] Visuospatial Processing Core	Measures of fine-motor, visual-motor, motor-free visual spatial skills,	Test–retest reliability for visuospatial processing core (5- to 12-year-olds) (r= 0.83). Average stability coefficient for visuospatial processing subtests (r= 0.70). Moderate to high criterion validity correlating significantly with other neuropsychological measures.

TABLE 2. Summary and Description of Standardized Assessments (Continued)

Test	Description	Reliability and Validity
Adaptive Behavior		
Scales of Independent Behavior–Revised (SIB-R)[a] (Bruininks, Woodcock, Weatherman, & Hill, 1996)	Caregiver report of adaptive behavior, maladaptive behavior, and four domains of function: (a) motor, (b) social interaction and communication, (c) personal living, and (d) community living. Items scored on a 4-point Likert scale ("0" = child can't do the task even if asked to; "3" = child almost always does task independently, does it well).	Test–retest reliability for broad independence score and cluster scores ($r > 0.95$). Test–retest reliability coefficients for Maladaptive Behavior Indices ($r = 0.80$ to 0.83). Parent inter-rater reliabilities for cluster scores and broad independence score ($r = 0.88$ to 0.95) and Maladaptive Behavior Indices ($r = 0.78$ to 0.86).
School Performance		
Wide Range Achievement Test, Third Edition (WRAT-3)[b] (Wilkinson, 1993)	Three subtests measure basic reading, spelling, and arithmetic achievement.	Internal consistency for three subtests (Cronbach's alpha = 0.85 to 0.95). Test–retest reliability coefficients ($r =$ 0.91 to 0.98). Subtest intercorrelations ($r = 0.66$ to 0.87). Moderate criterion validity correlations with other measures of academic achievement.
Social Skills Rating System (SSRS)–Teacher[c] (Gresham & Elliot, 1990)	Three scales measure teacher report of social development: (a) social skills, (b) problem behaviors, and (c) academic competence. Items scored by rating frequency of behaviors on a 3-point scale (0 = "never" and 2 = "very often").	Internal consistency for three scales (Cronbach's alpha = 0.88 to 0.95). Test–retest reliability for teacher ratings ($r = 0.84$ to 0.93). High criterion validity correlating significantly with other measures of social and problem behavior by report.
Intellectual Estimate		
Test of Nonverbal Intelligence, Second Edition (TONI-2)[b] (Brown, Sherbenou, & Johnson, 1990)	Language-free, motor-reduced, and culture-reduced measure of cognitive ability involving abstract/figural problem solving.	High internal consistency (Cronbach's alpha = 0.95). Test–retest reliability ($r = 0.86$). Test–retest stability over one week($r = 0.85$). High criterion validity correlating significantly with other measures of intelligence.

[a]Administered to caregiver.
[b]Administered to child.
[c]Administered to teacher.

of Nonverbal Intelligence, Second Edition (TONI-2) score entered as a covariate was used to assess group contrasts between mean scores measured on continuous scales. Pearson correlation coefficients were computed to assess correlations between outcomes measured on continuous scales. Chi-square tests for independence were used to assess group contrasts in proportions. Significance levels were set at a two-tailed alpha = 0.05. Exploratory analyses that tested relationships beyond the primary hypotheses were interpreted with caution because of the increased risk for type 1 error due to multiple comparisons.

RESULTS

Sensory Processing and Sensory-Motor Performance

Children with FASD performed more poorly than comparison peers across all measures of sensory processing and sensory-motor performance (Table 3; for test acronyms, see Table 2). Significantly lower mean ($p < .01$) scores on the Short Sensory Profile (SSP) and the Developmental Neuropsychological Assessment (NEPSY-SM) sensorimotor core domain and significantly higher mean scores on the Quick Neurological Screening Test-II (QNST-II) (indicating poorer performance) were found after adjusting for IQ. Relative to comparison peers, this means that children with FASD showed significantly more problems with sensory modulation, poorer sensory-motor performance, and more soft neurological signs.

The proportions of children in each SSP classification category of "normal" (above −1.0 standard deviation [SD]), "probable difference" (−1.0 to −2.0 SD), or "definite difference" (below −2.0 SD) were also analyzed for the total test and the seven subsections. Significantly more children with FASD (88%) had SSP total scores in clinically concerning categories (i.e., probable or definite difference) than the comparison group (30%), χ^2 (2, N= 48) = 17.84, $p < .001$. Significantly higher proportions of clinical classifications were also seen among the group with FASD on four of seven subsections: (a) Tactile Sensitivity χ^2 (2, N = 48) = 9.54, p = .008; (b) Underresponsive/Seeks Sensation χ^2 (2, N = 48) = 12.18, p = .001; (c) Auditory Filtering χ^2 (2, N = 48) = 21.21, p = .001; and (d) Visual/Auditory Sensitivity χ^2 (2, N = 48) = 9.62, p = .008). Lower scores for children with FASD, but no statistically significant categorical group differences, were seen on subsections of Taste/Smell Sensitivity, Movement Sensitivity, and Low Energy/Weakness.

TABLE 3. Descriptive Statistics and Mean Contrasts for Primary Test Variables by Group

	Fetal Alcohol Spectrum Disorders			Typical Development				
Test	*n*	M (SD)	Range	*n*	M (SD)	Range	Test Statistic	*p* Value[e]
Sensory Processing								
SSP[a]	25	125.0 (24.1)	78–170	23	159.2 (22.3)	101–184	$F = 18.27$	.001
Sensory-Motor Performance								
BOTMP[c]	25	49.1 (14.0)	24–72	26	57.7 (9.4)	37–75	$F = 0.85$	.36
QNST-II[a,d]	25	35.3 (9.6)	15–57	26	23.3 (6.6)	10–37	$F = 9.63$	<.01
NEPSY: Sensorimotor[b]	25	84.6 (16.1)	61–117	26	107.1 (10.9)	82–124	$F = 13.45$	.001
NEPSY: Visuospatial[b]	25	88.0 (18.6)	62–122	26	107.3 (13.2)	81–132	$F = 3.54$	.07
Adaptive Behavior								
SIB-R Broad Indep[b]	25	81.7 (23.7)	37–138	23	107.9 (14.02)	84–131	$F = 7.44$	.01
School Performance								
WRAT-3 Reading[b]	25	93.0 (16.7)	66–129	26	101.5 (14.8)	66–143	$F = 0.82$	.37
WRAT-3 Spelling[b]	25	86.1 (16.6)	53–124	26	100.8 (10.4)	78–122	$F = 5.34$	.03
WRAT-3 Arithmetic[b]	25	81.2 (14.0)	53–111	26	101.2 (13.05)	75–129	$F = 11.54$	.001
SSRS Social Skills[b]	21	96.8 (14.4)	67–124	24	101.3 (10.5)	83–128	$F = 0.44$	.51
SSRS Behavior[b,d]	21	108.9 (15.7)	85–138	24	94.4 (9.7)	85–110	$F = 8.39$	<.01
SSRS Academic[b]	20	92.3 (10.8)	67–109	24	99.3 (11.1)	79–115	$F = 1.25$	.27
Intellectual Estimate								
TONI-2[b]	25	91.2 (15.0)	60–128	25	107.2 (14.1)	82–136	$t = 3.88$	<.001

Bruininks-Oseretsky Test of Motor Proficiency (BOTMP); Developmental Neuropsychological Assessment (NEPSY); Quick Neurological Screening Test–II (QNST-II); Scales of Independent Behavior–Revised (SIB-R); Short Sensory Profile (SSP); Social Skills Rating System (SSRS); Test of Nonverbal Intelligence, Second Edition (TONI-2); Wide Range Achievement Test, Third Edition (WRAT-3).

[a]Raw score.

[b]Standard score (M = 100; SD = 15).

[c]Standard score (M = 50; SD = 10).

[d]Higher scores indicate poorer performance.

[e]Two-tailed *p* value for analysis of covariance after adjustment for IQ.

On the NEPSY core domains and the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the children with FASD had lower mean scores with distributions that showed more than the expected number of "low average" scores (Table 3). Performance on two NEPSY subtests was especially problematic for children with FASD. Average scores on the NEPSY Design Copying (Visuospatial Processing core domain) (mean [M] = 6.7, SD = 3.8) and Visual Motor Precision (Sensorimotor core domain) (M = 7.1, SD = 2.3) subtests were considerably lower than the respective comparison group scores (M = 11.3, SD = 3.5) and (M = 10.6, SD = 2.7).

Significantly more children with FASD (84%) than children with TD (28%) were also classified into clinically concerning categories of "moderate" or "severe" discrepancy versus "normal" on the QNST-II (Fisher's exact = 11.08, $p = .001$). Only 1 child (who was in the FASD group) was classified in the "severe discrepancy" category, so the moderate and severe categories were combined for this analysis. Scores on the QNST-II are derived from weighted observations on a series of sensory-motor tasks. The total raw score, which increases based on the number of observations considered atypical or immature, is then classified into one of three categories, "normal," "moderate discrepancy," or "severe discrepancy" (Mutti, Sterling, Martin, & Spalding, 1998).

School Performance

Children with FASD scored lower than children with TD across all three scales of the performance-based Wide Range Achievement Test, Third Edition (WRAT-3), with significant differences seen on the Spelling and Arithmetic (but not Reading) scales ($p < .05$) after adjusting for IQ (Table 3). Teacher ratings on the SSRS revealed significantly higher scores for children with FASD on the Problem Behaviors ($p < .01$) scale, indicating more problem behaviors in the classroom. Mean scores on the Social Skills and Academic Competence scales were lower, but not significantly, for children with FASD.

Adaptive and Maladaptive Behavior

Caregiver ratings revealed significantly lower adaptive skills for children with FASD on the Scales of Independent Behavior-Revised (SIB-R) composite score (Table 3). Congruent with teacher report, significantly far more children with FASD (78%) than comparison children (4%) demonstrated "marginally serious" or "moderately serious to serious" behavioral difficulties on the SIB-R General Maladaptive Behavior Index χ^2 (2, N = 45) = 25.20, $p < .001$.

Correlations between Primary Variables

A correlation matrix for the full sample (FASD and TD) is presented in Table 4. Nonverbal IQ was correlated with essentially all measures (and was therefore adjusted for when needed in prior analyses). Sensory processing behaviors (SSP) showed the strongest correlation with adaptive behavior (SIB-R) ($r = 0.58$, $p < .05$), both assessed through caregiver report. There were weaker but still significant relationships in the expected direction between sensory processing behaviors (SSP) and measures of sensory-motor performance on the QNST-II, NEPSY sensorimotor core domain (NEPSY-SM) and Visuospatial core domain (NEPSY-VP) (r = −0.33, 0.33, 0.39) respectively. The SSP was also significantly correlated with math ($r = 0.33$) and spelling ($r = 0.36$) achievement (WRAT-3). Surprisingly, no significant relationships were found between sensory processing behaviors (SSP) and teacher-rated school performance (SSRS).

The performance-based sensory-motor measures (i.e., NEPSY, BOTMP, QNST-II) showed moderate to moderately high correlations in the expected direction with adaptive behavior (SIB-R) (r = 0.48 to 0.67), as well as reading (r = 0.32 to 0.43), spelling (r = 0.52 to −0.60), and, most notably, math (r = 0.57 to 0.72) achievement on the WRAT-3. There were significant but weaker relationships between two sensory-motor performance measures, the QNST-II ($r = -0.31$) and the BOTMP ($r = 0.34$), with teacher-reported academic competence (SSRS).

Correlational data were further explored within the group with FASD to determine whether predicted associations held for this group of children with neurodevelopmental disabilities. Findings must be considered exploratory because of small sample size. Within the group with FASD, the association between sensory processing behaviors (SSP) and adaptive behavior (SIB-R) remained significant and moderately correlated (r = 0.42; $p < .05$). All sensory-motor performance variables were moderately correlated in the expected direction with adaptive behavior (NEPSY-SM r = 0.59; NEPSY VP $r = 0.57$; BOTMP $r = 0.48$; QNST-II $r = -0.45$; $p < .05$), and with math (r = 0.59 to 0.68; $p < .01$), spelling (r= 0.49 to 0.65), and reading (r= 0.46 to 0.52) ($p < .05$) achievement (WRAT-3). The correlations between the two sensory-motor performance variables and teacher-rated academic competence were no longer significant, perhaps due to decreased statistical power.

Finally, a linear test for trend was employed to examine the relationship between sensory processing behaviors (SSP) and problem behaviors

TABLE 4. Correlation Matrix for Primary Variables: Combined Sample of Children with Fetal Alcohol Spectrum Disorders and Typical Development

	1 SSP	2 BOTMP	3 QNST-II	4 NEPSY SM	5 NEPSY VP	6 SIB-R BI	7 WRAT Read	8 WRAT Spell	9 WRAT Math	10 SSRS Social	11 SSRS Behav	12 SSRS Acad	13 TONI-2
1 SSP	—	0.16	−0.33*	0.33*	0.39**	0.58**	0.20	0.36*	0.33*	−0.13	−0.25	0.17	0.35*
2 BOTMP		—	−0.68**	0.64**	0.60**	0.48**	0.32*	0.57**	0.57**	0.10	−0.13	0.34*	0.50**
3 QNST-II			—	−0.69**	−0.70**	−0.56**	−0.37**	−0.60**	−0.62**	0.01	0.27	−0.31*	−0.62**
4 NEPSY SM				—	0.66**	0.67**	0.38**	0.52**	0.57**	−0.04	−0.26	−0.29	0.68**
5 NEPSY VP					—	0.60**	0.43**	0.58**	0.72**	−0.05	−0.16	0.24	0.71**
6 SIB-R BI						—	0.35**	0.57**	0.64**	0.01	−0.31*	0.20	0.54**
7 WRAT-3 Reading							—	0.78**	0.48**	−0.11	0.01	−0.29	0.33*
8 WRAT-3 Spelling								—	0.66**	0.03	−0.10	0.40**	0.45**
9 WRAT-3 Math									—	0.15	−0.35*	0.52**	0.58**
10 SSRS Social									—	—	−0.60**	0.54**	−0.13
11 SSRS Behavior											—	−0.43**	−0.26
12 SSRS Academic												—	0.40**
13 TONI-2													—

*Sig. at 0.05 level (two tailed).
**Sig. at 0.01 level (two tailed).
Bruininks-Oseretsky Test of Motor Proficiency (BOTMP); Developmental Neuropsychological Assessment (NEPSY); Quick Neurological Screening Test–II (QNST-II); Scales of Independent Behavior–Revised (SIB-R); Short Sensory Profile (SSP); Social Skills Rating System (SSRS); Test of Nonverbal Intelligence, Second Edition (TONI-2); Wide Range Achievement Test, Third Edition (WRAT-3).

on the SIB-R General Maladaptive Behavior Index for the children with FASD. A linear test for trend was used for this analysis because the SIB-R Maladaptive Behavior Index is a categorical variable. Children with TD were not included in this analysis because only two children with TD were categorized in a problem behavior category. Lower mean SSP raw scores were significantly $F = (1, 22) = 12.27$, $p = .002$ associated with SIB-R behavioral classification categories of increasing severity as follows: “normal” (M = 146.6; SD = 15.5); “marginally serious” (M = 129.1; SD = 21.7); and “moderately serious to serious” (M = 105.6; SD = 21.5). This means that an increasing number of sensory processing problems were associated with a greater frequency and intensity of reported problem behaviors.

DISCUSSION

This study adds to the literature on the impact of prenatal alcohol exposure on children’s developmental outcomes by describing sensory processing deficits and decreased sensory-motor performance in a clinic-referred, clearly diagnosed sample of young, school-age children with FASD in comparison to typically developing peers. Among the children with FASD, significant academic, adaptive, and behavioral difficulties at home and school, consistent with existing literature on prenatal alcohol effects, clearly co-occurred. Although significant contrasts relative to a group of children with TD were expected, findings from this study are clinically important for OTs and PTs because marked sensory processing impairments and more subtle sensory-motor performance deficits were identified among a large proportion of children with FASD. Furthermore, several significant correlations provide preliminary support for the hypothesized relationships between sensory processing and sensory-motor impairments and decreased adaptive and academic function among children with FASD; findings that are consistent with the SI theoretical framework and that warrant further investigation.

Results support and expand initial descriptive evidence of SPD in children with FASD (Morse & Cermak, 1994; Morse et al., 1995). Methodological limitations of earlier studies were addressed by using a published, standardized measure of sensory processing behaviors (i.e., the SSP), a more rigorously balanced comparison group with a smaller age range, and a systematically diagnosed sample of children with FASD. The children with FASD in this study were three times more likely to be classified in a clinically significant category on the SSP than peers with TD, although sensory processing differences were also reported among children with TD, but at a much lower rate. Caregivers revealed that children with FASD demonstrated behavioral patterns of sensory overresponsivity to tactile, auditory, and visual stimuli, as well as patterns of sensory underresponsivity, sensation-seeking behaviors, and poor auditory filtering. Variable but significant difficulties modulating sensory information may contribute to the poor behavioral regulation often seen by parents and providers caring for children with FASD.

Deficits were not only revealed through parent report, but also in direct assessment of sensory-motor performance. Subtle but real and important differences among the children with FASD relative to peers with TD were found. As a group, the children with FASD overall showed more variability in performance and more often scored in a low average range or below on sensory-motor measures. Tasks requiring visual-motor speed and precision and design copying accuracy (two subtests from the NEPSY) appeared particularly problematic for the children with FASD. Indeed, fine-motor and visual-motor impairments, especially under timed conditions, have been among the more consistent findings in other clinical samples of children along the broader fetal alcohol spectrum (Admans et al., 2001; Mattson, Riley, Gramling, Delis, & Jones, 1998).

A high proportion of children with FASD also demonstrated "suspect" differences on clusters of sensory, motor, and perceptual tasks (often collectively referred to as "neurological soft signs") on the QNST-II. Although symptoms suggestive of developmental or neurologically based immaturities were observed in children from both groups, children with FASD were three times more likely to be classified in a clinically suspect category. Results draw attention to qualitative sensory-motor differences and inefficient motor performance among children with FASD, findings described (to some extent) in earlier clinical and longitudinal prospective studies of children prenatally exposed to alcohol, but documented here using a standardized measure (Kyllerman et al., 1985; Larrouque & Kaminski, 1998; Roebuck, Simmons, Mattson, & Riley, 1998).

Similar patterns of sensory-motor dysfunction and neuromaturational differences have been described as characteristic of children with SPD (Dahl-Reeves & Cermak, 2002; Lane et al., 2000; Parham & Mailloux, 2005). Thus, poor sensory processing may contribute to the diminished sensory-motor abilities seen among children with FASD, particularly those described clinically as more apparent under conditions of stress, novelty, or task complexity. More study of sensory-based motor disorders, praxis, and complex motor abilities in this clinical population is warranted.

Math deficits demonstrated in direct child testing, consistent with prior FASD literature, were among the prominent academic achievement findings in this study (Howell, Lynch, Platzman, Smith, & Coles, 2006). Teacher ratings of school performance clearly indicated more early behavior problems among the children with FASD, but surprisingly, teacher-rated academic and social skills were revealed as similar between the groups. Perhaps the latter contrasts were not significant because 14 (67%) of the children with FASD were receiving special education services (with SSRS norms for children with disabilities used accordingly), and the perceived academic and social abilities of these children were not markedly different from other students with disabilities at this young age. Whaley et al. (2001) reported that notable declines in social competence first emerged after age 8 years for children with FASD when compared to other clinical populations.

As predicted based on the SI theoretical framework, more sensory processing behavioral deficits were associated with poorer adaptive function and increased maladaptive behaviors in children with FASD. Decreased sensory-motor performance (which relied more heavily on praxis and motor output) was also associated with poorer adaptive function, as well as decreased academic achievement in all three domains. The predicted relationship between sensory processing behaviors (SSP) and teacher-rated classroom behaviors (i.e., social skills, problem behaviors), however, was not supported. Using context-specific measures, such as teacher-rated sensory processing measures, which were not available at the time of this study, may help better elucidate the impact of SPD in the classroom.

The high number of children with TD who demonstrated clinically elevated scores on two key measures (the SSP and QNST-II) was an unexpected finding. Because participants self-selected, it is possible that some caregivers of the children with TD had concerns about their child's development that were not clearly identified or diagnosed at the time of enrollment. However, clinically concerning scores were not uniformly seen across the other primary measures. As such, findings could be attributed to normal developmental variation, particularly on the QNST-II (Mutti et al., 1998). Alternatively, findings point toward measurement limitations (i.e., the specificity) of these screening tools. The measures in this study were selected for their clinical utility; however, future research clearly warrants expanded measurement of sensory processing abilities. The use of more comprehensive standardized tests such as the Sensory Integration and Praxis Test (Ayres, 1989) or psychophysiological or neuroimaging technologies, which have been recently employed to investigate SPD in other clinical populations, are important methods to consider to more fully examine SPD, and possibly subtypes of SPD, in children with FASD (Schaaf & Miller, 2005).

Clinically, sensory processing deficits appear to be an important, yet underrecognized problem among children with FASD. OTs and PTs are well placed to identify sensory processing and sensory-motor impairments among children with FASD. Awareness and recognition of SPD and the subsequent impact on behavior and motor performance can provide a framework from which to examine and understand some of the challenging behaviors and poor functional skills seen in young children with FASD. Indeed, "reframing" (i.e., understanding functional challenges from the standpoint of underlying CNS dysfunction) and the use of sensory-based accommodations have been suggested as important treatment processes in behavioral intervention with children with FASD in current clinical intervention research (Olson et al., 2005). How sensory processing deficits factor into the broader array of complex neurobehavioral problems in individuals with FASD, the extent to which these deficits impact specific behavioral and adaptive abilities, and the efficacy of interventions based on an SI framework for this population remain additional important questions that warrant future investigation.

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