Evidence Review to Investigate the Support for Subtypes of Children With Difficulty Processing and Integrating Sensory Information

Patricia L. Davies, Rebecca Tucker

We investigated the evidence for subtypes in children with difficulty processing and integrating sensory information. Fifty-seven articles were incorporated into a systematic literature review; only 4 articles provided direct evidence for subtypes. These studies did not provide a comprehensive assessment of all sensory functions and sensory-based motor functions (i.e., praxis) and included different diagnostic groups. Therefore, generalized conclusions about subtypes could not be drawn. The other 53 studies reviewed provided meaningful information about strengths and challenges that children with difficulty processing and integrating sensory information demonstrate, but these studies were limited in scope. A principal theme was the importance of conducting comprehensive assessments of sensory-based functions, including multiple measures of sensory integrative functions such as praxis, sensory modulation, and sensory discrimination in children and adolescents with various clinical disorders. In addition, more consistency in the use of specific assessment tools will allow for synthesis of data across studies.

Jean Ayres, the pioneer and founder of sensory integration theory and intervention, first coined the term sensory integrative dysfunction to describe sensory and motor problems in children with learning disabilities (Ayres, 1963, 1965). She proposed several different patterns of sensory integrative dysfunction in her early writings on the topic (Ayres, 1972a, 1972b). Later, Ayres (1989) refined these categories and identified six major patterns, two of which represent degrees of praxis, not distinct subtypes. Ayres (1972b) anticipated that identifying subtypes might help inform the type of treatment that might be most effective for a particular child. Since that time, practitioners and researchers have continued to investigate meaningful ways to group children with difficulty processing and integrating sensory information in an attempt to develop a classification system that represents the constellation of issues presented by children with this complex disorder; many of these studies are included in this review.

Background Literature

Ayres used child test data largely, but not exclusively, from the Southern California Sensory Integration Tests (SCSIT; Ayres, 1972b) or earlier forms of the SCSIT subtests (Ayres, 1965, 1966a, 1966b) to identify the initial subtypes of sensory integrative dysfunction. Using these data from typically developing children and children with perceptual and learning problems, Ayres (1972b) documented four categories of dysfunction that could be identified in children through the use of the SCSIT: form and space perception, praxis, postural and bilateral integration, and tactile defensiveness. These subtypes were consistent.
with her earlier studies (Ayres, 1965, 1966a, 1966b). Later, using data from the Sensory Integration and Praxis Tests (SIPT; Ayers, 1989), six clusters were identified: three subtypes of sensory integrative dysfunction (bilateral integration sequencing deficits, somatodyspraxia, visuodspraxia); a fourth cluster that was not considered a sensory integrative dysfunction (dyspraxia on verbal command); and two other clusters (low average sensory integration dysfunction and high average sensory integration function). Ayres suggested that these last two clusters represent degrees of function and do not assist in diagnosing subtypes (Ayres, 1989).

From the time of the seminal work of Ayres, several theorists and researchers in occupational therapy have proposed different taxonomies and subtypes for this complex set of behaviors. A few of these have been consistent with Ayres’ original work, yet others have reorganized and renamed them (Bundy & Murray, 2002; Miller, Anzalone, Lane, Cermak, & Osten, 2007). See Schaaf and Davies (2010) in this issue for a more comprehensive discussion of the evolution of this knowledge. Overall, there is inconsistency in the use of research data and lack of comprehensive studies to assist in defining subtypes. The purpose of this review was to search for, organize, and summarize the evidence that may support and describe subtypes of this complex set of symptoms referred to as sensory integrative dysfunction or sensory processing disorder.

Classification of Studies Reviewed

In our review of articles that investigated the evidence for subtypes of sensory integrative dysfunction or sensory processing disorder, we found that only a few studies directly provided evidence for subtypes. These studies revealed that a set or pattern of deficits in sensory functions and sensory-based motor functions (i.e., praxis), not just a single deficit in these areas, is best used to characterize subtypes. For example, several of these studies used data from the 17 subtests of the SIPT that assess aspects of visual perception; visual–motor skills; praxis; and vestibular, tactile, and proprioceptive functions to examine subtypes. The literature recommends that examination of the relationship among more than two variables at the same time (i.e., uncovering a pattern of characteristics that distinguishes different groups) requires a multivariate statistical approach using methods such as factor analysis, cluster analysis, discriminant analysis, or multidimensional scaling (Portney & Watkins, 2000). For this review, studies of this nature were classified as Class 1 articles. Studies that used univariate methods, such as a t test or analysis of variance, and contrasted groups on only one variable at a time were classified as Class 2 articles.

Method for Conducting the Evidence-Based Review

The articles included in this review had a publication date between 1986 and 2006 and included the entire range of sensory functions and sensory-based motor functions, including topics such as sensory modulation, sensory discrimination, dyspraxia, and specific sensory modalities. Detailed information about the methodology for the entire sensory integration evidence-based literature review can be found in the article “Methodology for the Systematic Reviews of Occupational Therapy for Children and Adolescents With Difficulty Processing and Integrating Sensory Information” in this issue (Arbesman & Lieberman, 2010).

Results

Table 1 summarizes the four Class 1 articles that provide direct evidence of subtypes of sensory integrative dysfunction or sensory processing disorder. Also included in this review are 53 studies that met the inclusion criteria but used univariate methods and thus were classified as Class 2, as previously discussed. These Class 2 studies are grouped according to diagnostic group: autism spectrum disorders (ASD; 16 articles); attention deficit hyperactivity disorder (ADHD; 10 articles); developmental coordination disorder (DCD; 15 articles); learning disabilities (LD; 5 articles); other diagnoses, such as dyslexia and fragile X syndrome (FXS; 3 articles); and, finally, several articles comparing more than one diagnosis in the same study (4 articles). The evidence table providing specific information such as level of evidence, sample size, and assessment tools for each article reviewed is available at www.ajot.ajotpress.net (navigate to this article, and click on “supplemental materials”).

Class 1 Article Results

Mulligan (1998) used an existing database of SIPT (Ayres, 1989) scores obtained from Western Psychological Services to conduct a factor analysis of 10,475 cases and a discrete group of 995 children with LD within that sample. The best fitting model for these data included a higher order model that included a general factor and four first-order factors that were all highly related and appeared to fall under one general concept. The general factor was described as praxic dysfunction. The four first-order factors were visual perceptual deficit, bilateral integration and sequencing deficit, dyspraxia, and somatosensory deficit.
A convenience sample was used. Some children (approximately half) also had a secondary diagnosis. Some of the children in the ADHD group were on medications and some were not. The children with ADHD performed significantly differently from the typically developing children on all 14 sections of the Sensory Profile, including auditory, touch, multisensory, emotional/social responses, and behavioral outcomes of sensory processing and specifically on 118 of 125 items. In each case, the children with ADHD displayed the behavior more frequently, with 57 of these 118 items showing more than 1 raw score point difference between the means. This analysis revealed that most of the items that were significantly different between the 2 groups fell into 4 of the 9 the previously defined factors (Dunn & Brown, 1997): sensory seeking, emotionally reactive, inattention/distractibility, and fine motor/perceptual.

### Table 1. Summary of the Evidence Supporting Subtypes of Children With Difficulty Processing and Integrating Sensory Information

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Study Objectives</th>
<th>Level/Design/Participants</th>
<th>Intervention and Outcome Measures</th>
<th>Results</th>
<th>Study Limitations</th>
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<tbody>
<tr>
<td>Dunn &amp; Bennett</td>
<td>The objective of this study was to compare sensory responsiveness of children with ADHD and typically developing children.</td>
<td>Level II Design Group comparison</td>
<td>No intervention was used.</td>
<td>The children with ADHD performed significantly differently from the typically developing children on all 14 sections of the Sensory Profile, including auditory, touch, multisensory, emotional/social responses, and behavioral outcomes of sensory processing and specifically on 118 of 125 items. In each case, the children with ADHD displayed the behavior more frequently, with 57 of these 118 items showing more than 1 raw score point difference between the means. This analysis revealed that most of the items that were significantly different between the 2 groups fell into 4 of the 9 the previously defined factors (Dunn &amp; Brown, 1997): sensory seeking, emotionally reactive, inattention/distractibility, and fine motor/perceptual.</td>
<td>A convenience sample was used. Some children (approximately half) also had a secondary diagnosis. Some of the children in the ADHD group were on medications and some were not. The children from the national standardization sample were not matched to the ADHD sample on characteristics such as socioeconomic status and ethnicity.</td>
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<tr>
<td>Liss, Saulnier,</td>
<td>The objective of this study was to examine whether sensory overreactivity can be explained by response to overarousal in a group of children with autism.</td>
<td>Level III Design Cross-sectional survey</td>
<td>No intervention was used.</td>
<td>Four stable clusters were derived from the results: 1. Cluster 1 (n = 17) featured overreactivity to sensory stimuli, perseverative behavior, high overfocusing, and an exceptional memory. 2. Cluster 2 (n = 36) members were relatively high functioning, were not seriously impaired, and exhibited few sensory problems. 3. Cluster 3 (n = 44) members were low functioning with prominent undersensitivity and sensory-seeking behaviors. 4. Cluster 4 (n = 47) members were low on autistic symptoms and high on adaptive functioning and sensory overreactivity but not as high as Cluster 1 in overfocusing and had an exceptional memory. When a 3-cluster solution is forced, Cluster 4 combines with Cluster 1, but this finding obscures the overfocusing of Group 1. Cluster 4 members were significantly older than the other clusters.</td>
<td>The study is of good quality.</td>
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<td>Fein, &amp; Kinsbourne</td>
<td></td>
<td>Parent questionnaires were filled out for 222 children who were on the autism spectrum. Parents of 191 children were contacted for follow-up data. Complete data sets were available for 144 children. Diagnoses were confirmed using DSM-IV criteria. The mean age of the children was 102.4 mo, and the sample was 79.9% male.</td>
<td>No intervention was used.</td>
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<tr>
<td>Mulligan</td>
<td>The objective of this study was to evaluate and confirm the 5-factor model of sensory integration dysfunction on the basis of the Sensory Integration and Praxis tests (SIPT). The hypothesized model of Level III Design Cross-sectional 10,475 existing SIPT test scores were used. They were obtained from 1989 to 1993. Most children in the group had mild disabilities. The entire sample</td>
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<td>No intervention was used.</td>
<td>All 5 patterns of dysfunction were highly correlated with each other. The original hypothesized model had a reasonable fit, but there were weaknesses such as the high correlation between factors. Thus, additional 3-factor, 4-factor, and 5-factor solutions were examined. These revised models eliminated the postural ocular movement pattern and included a praxis pattern in place of the somatopraxis pattern.</td>
<td>The group of children with learning disabilities may not have been accurately characterized by the therapists conducting the SIPT. This, thus, may not have been a homogeneous group.</td>
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The 4 first-order factors that were involved with the best model were visuoperceptual deficit, bilateral integration and sequencing deficit, dyspraxia, and somatosensory deficit.

4 subtests of the SIPT have weak test–retest reliability.

The time window of when the tests were administered was quite long (4 yr). This could introduce confounding factors, including history. Only children who had a suspected sensory integration problem (most were receiving special education) were included in the sample, reducing the generalizability to other populations.

Note. ADHD = attention deficit hyperactivity disorder; DSM–IV = Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (American Psychiatric Association, 2000); SIPT = Sensory Integration and Praxis Tests.
A second study conducted by Mulligan (2000) used a cluster analysis on 1,961 heterogeneous cases. Mulligan found the five-cluster result most meaningful: Cluster 1, generalized sensory dysfunction and dyspraxia—severe (11.2% of the sample); Cluster 2, dyspraxia (29.6% of the sample); Cluster 3, generalized sensory dysfunction and dyspraxia—moderate (8.4% of the sample); Cluster 4, low-average bilateral integration and sequencing (36.6% of the sample); and Cluster 5, average sensory integration and praxis (14.2% of the sample). Although these five factors appear to relate most to the severity of the dysfunction, it is noteworthy that dyspraxia and bilateral integration and sequencing were again identified as discrete patterns or subtypes.

Liss, Saulnier, Fein, and Kinsbourne (2006) evaluated patterns of sensory reactivity (i.e., potential subtypes) in children with ASD. An advantage of this study is that unlike the previous two studies, which used only one assessment (SIPT), this study included multiple assessments that evaluated specific aspects of sensory processing (a Sensory Questionnaire—Liss, Saulnier, & Fein, 1998—with some questions from the Sensory Profile; Dunn, 1999), adaptive behavior (the Vineland Adaptive Behavior Scales; Sparrow, Balla, & Cicchetti, 1984), and information-processing abilities such as memory and attention (Kinsbourne Overfocusing Scale; Kinsbourne, 1991). A cluster analysis was performed on data collected from 254 participants (mean age = 8 yr, 6 mo) revealing four stable clusters. Cluster 1 consisted of children (11.8% of the sample) who were oversensitive to sensory stimulation and had high scores on overfocused selective attention and were most impaired on social skills. Cluster 2 consisted of children (25% of sample) who were relatively high functioning and exhibited no or very few sensory problems. Cluster 3 consisted of children (30.6% of sample) who were low functioning, especially with communication and social skills; were undersensitive; and displayed sensory-seeking behaviors. Cluster 4 consisted of children similar to those included in Cluster 1 but their symptoms were not as severe as those of the children in Cluster 1 and they were older (32.6% of sample). The results of this study suggested that children and adolescents diagnosed with ASD display different clusters of behavior that are associated with reactivity to sensation.

Dunn and Bennett (2002) examined Sensory Profile scores of children with ADHD and compared them to scores of children without disabilities, utilizing factors from Dunn and Brown’s (1997) previous study. Dunn and Brown conducted the factor analysis of the Sensory Profile data collected on typically developing children. Thus, this article did not meet the inclusion criterion for this systematic review because it did not include children with disabilities. Dunn and Brown conducted a factor analysis on the Sensory Profile scores from 1,115 children without disabilities. The Sensory Profile consists of 120 caregiver questions about children’s behaviors in response to sensory events in their daily life. The results yielded nine factors: sensory seeking, emotionally reactive, low endurance/tone, oral sensory sensitivity, inattention/distraction, poor registration, sensory sensitivity, sedentary, and fine motor/perceptual. The analysis conducted by Dunn and Bennett (2002) on children with ADHD revealed that most of the items that significantly distinguished the children with ADHD from typically developing children fell into four of the nine previously defined factors: sensory seeking, emotionally reactive, inattention/distraction, and fine motor/perceptual. Multivariate analyses are needed to confirm these findings.

Class 2 Article Results Grouped by Diagnostic Population Studied

Autism Spectrum Disorders. Various studies investigated sensory functions and sensory-based motor functions (such as motor planning, balance, gait, and postural control) among children with ASD. Several studies indicated that children with ASD have difficulty with gait and balance (e.g., smaller steps, slower speed, lack of postural control, and dysrhythmia) compared with typically developing children (Jansiewicz et al., 2006; Vernazza-Martin et al., 2005) and rely on visual input to maintain balance more than do typically developing children (Minshew, Sung, Jones, & Furman, 2004; Molloy, Dietrich, & Bhattacharya, 2003). During a locomotor task (Vernazza-Martin et al., 2005) and in upper-extremity movements (Rinehart et al., 2006), children with ASD displayed deficits in motor planning.

In terms of single sensory systems, children with ASD demonstrated strengths and challenges in visual and auditory processing. Identifying embedded figures and detecting objects in a visual search task are strengths for children with ASD compared with typically developing children matched by mental age, but when attention is required, visual search becomes deficient in children with ASD (Jarrold, Gilchrist, & Bender, 2005). Brain physiological studies, using magnetoencephalography and electroencephalography, have demonstrated that children with ASD do not show typical maturational changes in brain regions processing the simple auditory tones or the same degree of brain activity in response to simple or novel tones as typically developing children (Ceponiene et al., 2003; Tecchio
The children with ASD also showed less brain processing in response to vowels when compared with the control group, which may indicate that children with ASD have difficulty processing speech sounds (Cepioniene et al., 2003). Enhanced auditory discrimination was a strength for children with ASD compared with control children (O’Riordan & Passetti, 2006). By contrast, children with ASD demonstrated similar tactile discrimination when compared with typically developing children (O’Riordan & Passetti, 2006).

Sensory modulation symptoms were examined using parent questionnaires in a few studies. Scores on the Sensory Profile indicated that children with ASD had difficulties with sensory modulation when compared with the typically developing children, especially in the categories of emotionally reactive and poor sensory registration (Watling, Deitz, & White, 2001). When relating parents’ report of their child’s sensory processing to parents’ report of the child’s anxiety and depression symptoms, a relationship between sensory hypersensitivity (sensory sensitivity and sensory avoiding) and anxiety was found as well as a relationship between hyporesponsiveness and depression (Pfeiffer, Kinnealey, Reed, & Herzberg, 2005).

Several studies using parent or self-report questionnaires across ages 3–56 indicated that people with ASD showed significantly more dysfunction, especially hypersensitivity to sensory input across all modalities, in everyday activities when compared with age-matched, typically developing groups (Baranek, David, Poe, Stone, & Watson, 2006; Davis, Bockbrader, Murphy, Hetrick, & O’Donnell, 2006; Kern et al., 2006).

**ADHD.** Several studies using parent- or self-report questionnaires found sensory modulation difficulties such as increased sensory seeking, reactivity, and sensitivity in children with ADHD compared with a typically developing group of children. Children with ADHD displayed significant deficits on many sections of the Sensory Profile compared with typically developing children (Dunn & Bennett, 2002; Yochman, Ornoy, & Parush, 2006; Yochman, Parush, & Ornoy, 2004). One study examining electroencephalography during somatosensory processing demonstrated that children with ADHD displayed increased cortical brain activity to somatosensory stimulation and displayed significantly more tactile defensiveness compared with typically developing children on a behavioral assessment (Parush, Sohmer, Steinberg, & Katz, 1997).

Several studies examined perceptual timing and duration discrimination in visual and auditory domains. Children with ADHD did not display a deficit in perceptual timing in the visual domain, but they did show an increased variability in timing of motor responses compared with a typically developing children (Rubia, Taylor, Taylor, & Sergeant, 1999). Another study using virtual reality technology simulating a table tennis task found that adolescents with ADHD displayed difficulties in timing when a visual cue was displayed for long durations (i.e., 2 s), but not for short durations (i.e., 350 ms) compared with typically developing adolescents (Vickers, Rodrigues, & Brown, 2002). The results suggest that adolescents with ADHD have difficulty sustaining eye tracking on moving objects, especially in tasks that require extended visual attention. Another study showed that adolescents with ADHD have difficulty sustaining eye tracking on moving objects, especially in tasks that require extended visual attention. Another study showed that adolescents with ADHD displayed significantly poorer abilities in the discrimination of duration of both visual and auditory stimuli (Toplak & Tannock, 2005).

**DCD.** A meta-analysis examining overall perceptual and motor measures indicated that children with DCD have a mild, nonspecific performance deficit associated with motor impairment and indicated that many children with DCD have visuospatial skill deficits (Wilson & McKenzie, 1998). Several other studies investigated visual closure, visual–motor coordination, or balance in children with DCD or motor coordination difficulties (Forseth & Sigmundsson, 2003; Sigmundsson, Hansen, & Talcott, 2003; Sigmundsson & Hopkins, 2005; Van Waelvelde et al., 2006; Van Waelvelde, De Weerdt, De Cock, & Smits-Engelsman, 2004). The results of these studies found that children with motor clumsiness or DCD demonstrated significant deficits performing visual closure, visual–perceptual and visual–motor coordination tasks. Children with DCD also showed significant movement coordination difficulties on several assessments compared with typically developing groups of children. One of these studies demonstrated that when performing rhythmic movements, children with DCD depended on visual input for successful performance more so than typically developing children. However, the same was not true for auditory input; both groups performed equally well (Van Waelvelde et al., 2006).

Ameratunga, Johnston, and Burns (2004) and Coleman, Piek, and Livesey (2001) found that children with DCD displayed difficulties with kinesthetic abilities. Children with DCD benefited more from sensory input, both visual and kinesthetic, during a reaching task, but they did not benefit from receiving sensory input during instructions or cueing before the reaching task (Ameratunga et al., 2004). Children with DCD also had difficulty developing visuomotor maps (i.e., in a repetitive task, the children with DCD were not able to remember the path of movement) and lacked smoothness of movements compared with the typically developing.
children (Kagerer, Bo, Contreras-Vidal, & Clark, 2004). Children with DCD displayed sensory organization deficits in the control of balance, especially in conditions that presented sensory conflict when tested with a dynamic posturography test (Inder & Sullivan, 2005). Another study using electromyography indicated that children with DCD showed deficits in controlling their balance compared with a typically developing children (Geuze, 2003, 2005).

Several studies examined motor coordination in relationship to performing gestures and imagined movements. Children with DCD have difficulty coordinating movements, especially when the only cues provided are verbal instructions, suggesting difficulty with auditory processing (Zoia, Pelamatti, Cuttini, Casotto, & Scabar, 2002). In a unique study examining actual movements compared with imagined movements, children with DCD performed significantly differently from a group of typically developing children for imagined arm movements but not for real arm movements (Wilson, Maruff, Ives, & Currie, 2001). These results suggest that children with DCD may have difficulties constructing or planning movements in the absence of sensory feedback from actually performing the movement.

Learning Disabilities. Children with a nonverbal LD performed worse on spatial visualization, visual–motor skills, and visual–perceptual tasks compared with children who had coordination, sensory integration, and school-related difficulties but no LD (Humphries, Krekewich, & Snider, 1996).

Several studies examined the difference between subgroups of children with LD on sensory-based motor performance. Children with LD demonstrated sensory-based motor performance deficits in fine and gross motor coordination and balance compared with control participants (Murray, Cermak, & O’Brien, 1990; O’Brien, Cermak, & Murray, 1988; Stoodley, Fawcett, Nicolson, & Stein, 2005). One longitudinal study examined whether children with LD demonstrated decreased sensory-based motor performance compared with age-matched peers over a 3-year period. The results indicated that children with LD “catch up” on motor coordination and speed tasks; however, the children with LD showed a consistent deficit over 3 yr on stereognosis and graphesthesia, which involve more complex tactile skills (Snow, Blondis, Accardo, & Cunningham, 1993).

Other Diagnoses. Two studies examined the sensory processing characteristics of children with FXS. Sensory symptoms were found to be high in children with ASD and FXS, and the participants with fewer sensory symptoms were found to have higher adaptive behavior skills (Rogers, Hepburn, & Wehner, 2003). Another study found that increased hyperresponsiveness to sensory stimuli in children with FXS related to decreased occupational performance (Baranek et al., 2002).

One study examined the sensory processing skills of children who had spent time in an institution. The results demonstrated that children with a longer time spent institutionalized had more motor planning (praxis) and sensory modulation problems compared with children who spent less time in an institution (Lin, Cermak, Coster, & Miller, 2005).

Comparison of Several Diagnoses. Several studies examined sensory function and sensory-based motor performance in groups of children with different diagnoses. These studies may assist in understanding and differentiating patterns of sensory functions and sensory-based motor performance among children with different diagnoses. The factors of the Sensory Profile discriminated between typically developing children, children with ADHD, and children with ASD. The inattention/distractibility function of the Sensory Profile discriminated best between children with and without disabilities. Sensory seeking, oral sensory sensitivity, and fine motor/perceptual discriminated best between children with ADHD and ASD (Ermer & Dunn, 1998). A separate study examined Sensory Profile scores in children with ASD, FXS, Down syndrome, and other developmental delays compared with typically developing children (Rogers et al., 2003). Children with ASD and FXS had significantly more sensory symptoms than did the other groups. Children with ASD had the most symptoms on the taste and smell category compared with other groups. Children with FXS were reported to have the most symptoms on low energy/weak muscles compared with the other child groups.

Children with LD and ADHD have more difficulties with central auditory processing compared with children with just ADHD or children without disabilities (Gomez & Condon, 1999).

A few studies compared sensory-based motor performance in children with different diagnoses or children with comorbid diagnoses. A study examining sensory-based motor performance and motor coordination in children with both DCD and LD revealed that these children experience motor planning problems with difficulty in fast projective movements, which is a high-level, sensory-based motor skill requiring feed forward abilities (Smits-Engelsman, Wilson, Westenberg, & Duyssens, 2003).

Discussion and Implications for Practice

Only a few studies included in this review directly tested whether children and adolescents with difficulty processing
and integrating sensory information can be classified into subtypes. Of these studies, two studies examined subtypes using an existing database of SIPT scores from a heterogeneous sample of children (therapists reported that the children exhibited mild disabilities such as LD, behavioral difficulties, or motor difficulties). Another study examined subtypes in a sample of children diagnosed with ASD using several measures including reactivity, adaptive function in communication, socialization and activities of daily living, and cognitive abilities such as memory and attention. Another study that directly examined subtypes used the Sensory Profile scores in children with ADHD (Dunn & Bennett, 2002) on the basis of Sensory Profile factors identified in typical children (Dunn & Brown, 1997). One major drawback of these Class 1 studies is that they use different assessments to examine heterogeneous populations. For example, Ayres (1972b, 1989) and Mulligan (1998, 2000) used the SIPT that has several tests of praxis and limited tests of sensory modulation, whereas Dunn and Bennett (2002) and Liss et al. (2006) used a parent sensory questionnaire, which has many items assessing sensory modulation but limited items evaluating praxis. A second limitation is that these Class 1 studies used different clinical populations. Mulligan (1998, 2000) used a heterogeneous sample of children; the therapists reported that the children had mild disabilities such as learning disabilities, behavior difficulties, and motor difficulties. By contrast, Dunn and Bennett (2002) used a typically developing population and children with ADHD. Thus, interpreting these studies as a group to determine subtypes must be done with these limitations in mind.

Of the Class 1 studies using the SIPT, Mulligan’s (1998, 2000) research supported the subtypes identified by Ayres (1972b, 1989) with one exception. The original Ayres (1972b) classifications included the subtype of tactile defensiveness, whereas Mulligan’s (1998, 2000) classifications did not. It is possible that the results may have revealed entirely different and unique subtypes had these studies included additional items that examined sensory modulation. Because many items on the SIPT evaluate some aspect of praxis, it is not surprising that the subtypes revealed were highly related and praxis based. Consistent with the earlier work by Ayres (1972b, 1989), discrete subtypes of sensory integrative dysfunction were found, specifically, dyspraxia and bilateral integration and sequencing. In a recent interpretation of the 1998 study, Mulligan now prefers to interpret the general factor as sensory integration dysfunction rather than only praxis dysfunction (personal communication, July 30, 2007).

The Liss et al. (2006) study examined subtypes in children with ASD, using a parent sensory questionnaire, and found four patterns of behavior that related to sensory reactivity. One pattern consisted of being hypersensitive to sensory input. By contrast, another group of children exhibited underresponsiveness to sensory input and sought sensory input. Approximately 30% of the children with ASD in this study did not display sensory processing deficits at all. This finding suggests that not all children with ASD display similar patterns of behavior and sensory reactivity and, thus, systematic clinical evaluations should be conducted to inform occupational therapists about which treatment strategies are needed to address sensory modulation and reactivity in children with ASD.

Dunn and Bennett’s (2002) study examining sensory behaviors and subtypes in children with ADHD revealed that the items on the Sensory Profile that distinguished between children with ADHD and typical peers fell into four of the nine factors (Dunn & Brown, 1997): sensory seeking, emotionally reactive, inattention/distractibility, and fine motor/perceptual.

The research reported in the Class 1 articles provides some support to suggest that subtypes related to sensory functions exist and that treatment strategies may need to vary depending on the sensory characteristics of the child. Research on subtypes within particular diagnoses is beginning to find a specific pattern or several discrete patterns or subtypes within a diagnosis. Examples of this were shown with children with ASD (Liss et al., 2006) and children with ADHD (Dunn & Bennett, 2002).

The Class 2 studies that were reviewed provide some useful information regarding diagnosis-specific patterns related to sensory processing. The review of the Class 2 studies was included to provide guidance to researchers and practitioners about sensory functions and sensory-based motor characteristics that should be considered for inclusion in future research, but they do not provide direct information about subtypes.

For example, children with ASD demonstrated strengths in tasks requiring visual and auditory discrimination (Jarrold et al., 2005; O’Riordan & Passetti, 2006). Visual discrimination, such as when visually searching for objects, is a strength, however, only when other attention demands are not required (Jarrold et al., 2005). Therapists could capitalize on these visual and auditory processing strengths by incorporating other sensory systems or cognitive demands to increase integration of sensory input while deriving benefit from the visual and auditory systems. In addition, children with ASD were shown to rely more on visual input than on vestibular, somatosensory, or proprioceptive input while maintaining balance. This finding suggests that consistent sensory input received
from the visual system may offset difficulties experienced with the vestibular, somatosensory, and proprioceptive systems (Minshew et al., 2004; Molloy et al., 2003).

Several studies found that children with ASD have more disturbances in postural control and motor planning than with balance, equilibrium, or motor execution (Jansiewicz et al., 2006; Rinehart et al., 2006; Vernazza-Martin et al., 2005). When planning intervention for motor functioning in everyday activities, occupational therapists should be aware of these strengths along with the deficits in praxis and balance. For example, instead of focusing on the actual execution of a motor activity or balance, therapists could engage the child in activities that emphasize motor planning and postural control (e.g., maneuvering through an obstacle course, playing “Simon Says,” jumping rope).

Children with ADHD were shown to have sensory processing deficits across modalities (Dunn & Bennett, 2002; Parush, Soher, Steinberg, & Kaitz, 1997; Yochman et al., 2004, 2006). One study found sensory-based motor deficits in preschool children with ADHD (Iwanaga, Ozawa, Kawasaki, & Tsuchida, 2006). However, in another set of studies reviewed, children with ADHD were not shown to have difficulties with fundamental sensory-based motor performance, but they were shown to have difficulty with complex, higher level sensory processing abilities involving sustained visual attention on moving objects and discrimination of the duration of visual and auditory stimuli (Toplak & Tannock, 2005; Vickers et al., 2003). These deficits would be evident in activities involving timing and synchronization of limbs. For example, in playing tennis, processing sound from an opponent’s racket hitting the ball and sustaining visual contact on a fast-moving ball coming toward one’s own racket is required for successful participation. Intervention involving the enhancement of these higher level sensory processing skills should build on the strength of the rudimentary skills and advance to more complex feed-forward activities (e.g., an individual moving to meet a moving object).

For children with DCD, in addition to motor planning or praxis difficulties, specific difficulties processing visual information have been noted, especially in tasks requiring visual perception (e.g., visual motor and visuospatial) and visual–motor coordination. Children with DCD were found to rely more heavily on their vision when performing tasks involving motor coordination and balance than did typically developing children (Van Waelvelde et al., 2006); however, this was not the case for auditory cues. These findings suggest that during assessment and intervention, especially for a difficult task, the practitioner may desire to provide visual cues at the beginning and grade the activity by decreasing the visual cues as the individual becomes more proficient and independent. This finding highlights that using multisensory instructions and cues could be beneficial. Interestingly, no studies in this review evaluated sensory modulation or sensory discrimination performance in children with DCD.

Finally, children with LD, similar to children with DCD, were found to have difficulties in visual processing, especially spatial visualization and visual–motor skills (Humphries et al., 1996; O’Brien et al., 1988). Deficiencies in sensory-based motor function and motor coordination were found in children with LD (O’Brien et al., 1988; Snow et al., 1993; Stoodley et al., 2005). Difficulties in sensory-based motor function and motor coordination seen in children with both DCD and LD may be attributed to the lack of ability to predict consequences of their movement actions (Smits-Engelsman et al., 2003). This inability could be caused by lack of sensory feedback, not slowness or limited information processing. Graphasthesia and stereognosis continue to be problematic for many children with LD, whereas children with LD appear to overcome the difficulties of motor coordination and speed tasks as they mature. Thus, tasks that involve more complex tactile discrimination skills should be considered in assessment and treatment when working with children with LD. Sensory modulation performance in LD was not evaluated in the articles included in this review.

Assessment and Research

Four important themes regarding assessment and future research in the area of sensory integration and sensory processing emerged from this review. First, when analyzing research on subtypes of sensory integration dysfunction and sensory processing disorder, it is important to pay close attention to the assessments used. As we saw in the Ayres (1972b, 1989) and Mulligan (1998, 2000) studies compared with the Dunn and Bennett (2002) and Liss et al. (2006) studies, the different assessment items yielded different factors or cluster groups. This finding highlights the need for a comprehensive assessment of sensory function and sensory-based motor performance that includes sensory perception, discrimination, modulation, and praxis in a single study. Second, this review suggests that the clinical diagnosis affects the subtypes found. For example, children with ASD were found to have different sensory function and sensory-based motor strengths than those with DCD. Third, sensory integration and sensory processing are constructs that are evolving, and
it is important to determine whether a particular study assessed a single sensory processing attribute, multiple processing characteristics, or integration of multiple sensory modalities (see Schaaf & Davies, 2010, in this issue, for a more in-depth discussion of this issue). Determining what aspect of sensory processing or integration is being studied—the detection of the sensory stimulus, the interpretation of the sensory stimulus, the regulation of the sensory input, the integration of two or more sensory modalities, or the sensory-based behavioral response—will be essential to future studies using neuroscience techniques. Finally, research using multivariate approaches is needed to confirm or dispute the concept of subtypes of sensory integrative dysfunction or sensory processing disorder. Measures of sensory functions and sensory-based motor behaviors and measures of other constructs such as information processing, ocular–motor abilities, and adaptive behaviors, will be helpful in distinguishing these “other” construct attributes from the sensory-based characteristics and how they may covary. Thus, studies that include multiple assessment items and tools will increase our capability to capture patterns of sensory processing abilities that lead to function or dysfunction in everyday activities. ▲

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References


*indicates studies that were systematically reviewed for this article and are listed in the evidence table available at www.ajot.aotpress.net.


