Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology

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Abstract

Children with attention deficit hyperactivity disorder (ADHD) are impulsive, inattentive and hyperactive, while children with sensory modulation disorder (SMD), one subtype of Sensory Processing Disorder, have difficulty responding adaptively to daily sensory experiences. ADHD and SMD are often difficult to distinguish. To differentiate these disorders in children, clinical ADHD, SMD, and dual diagnoses were assessed. All groups had significantly more sensory, attention, activity, impulsivity, and emotional difficulties than typical children, but with distinct profiles. Inattention was greater in ADHD compared to SMD. Dual diagnoses had more sensory-related behaviors than ADHD and more attentional difficulties than SMD. SMD had more sensory issues, somatic complaints, anxiety/ depression, and difficulty adapting than ADHD. SMD had greater physiological/electrodermal reactivity to sensory stimuli than ADHD and typical controls. Parent-report measures identifying sensory, attentional, hyperactive, and impulsive difficulties varied in agreement with clinician's diagnoses. Evidence suggests ADHD and SMD are distinct diagnoses.

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Introduction

Attention deficit hyperactivity disorder (ADHD) is an early childhood developmental disorder that has received enormous attention in research. Typical characteristics of ADHD are developmentally inappropriate impulsivity, inattention, and hyperactivity (Barkley & Murphy, 1998; Kaplan, Sadock, & Grebb, 1994). ADHD is a costly and prevalent childhood disorder that affects 3–12% of school-aged children (Froehlich et al., 2007; Schachar, 2000) and accounts for approximately half of all pediatric referrals to mental health services (CDC, 2003; Glicken, 1997; Goldman, Genel, Bezman, & Slanetz, 1998).

Another early childhood developmental disorder, which has received less attention, is Sensory Processing Disorder (SPD) (Miller, Anzalone, Lane, Cermak, & Osten, 2007). The essential features of SPD are the presence of difficulties in detecting, modulating, interpreting and/or organizing sensory stimuli, which are so severe that it interferes with daily life routines. The presence of sensory symptoms may be as prevalent as ADHD (Ahn, Miller, Milberger, & McIntosh, 2004; Ben-Sasson, Carter, & Briggs-Gowan, 2009; Gouze, Hopkins, Lebailly, & Lavigne, 2009). For decades, large numbers of children have been identified as having sensory-based disorders by occupational therapy clinicians and others. Although, wide-spread skepticism exists among many health professionals about SPD and its treatment (e.g., Arendt, MacLean, & Baumeister, 1988; Hoehn & Baumeister, 1994; Polatajko, Kaplan, & Wilson, 1992; Schaffer, 1984; Vargas & Camilli, 1999), SPD is recognized by both the Diagnostic Manual for Infancy and Early Childhood (Interdisciplinary Council on Developmental and Learning Disorders (ICDL-DMIC), 2005) and the Zero to Three Diagnostic Classification of Mental Health and Developmental Disorders of Infancy and Early Childhood: Revised edition (DC:0-3R; Zero to Three, 2005), both of which focus on subtypes of one classic pattern of SPD called sensory modulation disorder (SMD). The prevalence of sensory symptoms is estimated to be 5–16% in the normal population (Ben-Sasson, Hen et al., 2009; Gouze et al., 2009) and 30–80% in individuals with developmental disabilities (Ahn et al., 2004; Baranek, Foster, & Berkson, 1997; Ben-Sasson, Hen et al., 2009; Tomchek & Dunn, 2007).

While evidence suggests that neither ADHD nor SPD are homogeneous conditions, some of the behaviors characteristic of ADHD overlap with those observed in SPD. Therefore, one important question is whether ADHD and SPD are distinct disorders, the same disorder or manifest as co-morbid disorders. The current Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-R, 2000) does not recognize SPD as a separate clinical disorder. However, efforts have been directed toward the inclusion of SPD as a ‘novel diagnosis’ (D. Pine, personal communication). Additionally, there are questions about the validity of the traditional ADHD subtypes (e.g., Widiger & Samuel, 2005).

Three ADHD subtypes are described in the current DSM-IV-R: predominantly inattentive; predominantly hyperactive and impulsive; and combined inattentive and hyperactive/impulsive. ADHD/hyperactive impulsive (ADHD/HI) is characterized by excessive and situationally inappropriate motor activity (Halperin, Matier, Bedi, Sharma, & Newcorn, 1992) and limited inhibitory control of responses (Barkley, 1997; Chelune, Ferguson, Koon, & Dickey, 1986; Nigg, 2000), whereas ADHD/inattentive (ADHD/I) is characterized by an impaired ability to focus, sustain, and switch attention (Cepeda, Cepeda, & Kramer, 2000; Levine, Busch, & Aufseeser, 1982; Seidel & Joschko, 1990). Some children have both types of ADHD referred to as ADHD/combined (ADHD/C). Children with all types of ADHD face daily challenges with learning and achieving at school, behaving appropriately at home, and participating fully in their communities due to difficulty controlling impulsive behavior, sustaining attention, and regulating activity levels.

One primary pattern within SPD is sensory modulation disorder (SMD), which is characterized by difficulty regulating and organizing responses to sensory input. SMD includes three subtypes delineated by a recent nosology (Miller, Anzalone, et al., 2007) as well as in two developmental diagnostic manuals for young children (ICDL-DMIC, 2005; Zero to Three, 2005): Sensory-Over-Responsivity (SOR), Sensory-Under-Responsivity (SUR), and Sensory-Seeking/Craving (SS/C). Children with SOR feel sensations too intensely, for a longer duration than is typical and/or may over-respond with atypical behaviors such as temper tantrums, screaming or moving away from stimulation. Often these children try to keep their behaviors under control at school where they are exposed to multisensory input, only to become disregulated when they come home. SUR describes children who respond less to or take longer to respond to input. These children often appear withdrawn or seem to be ''in their own world.'' They have difficulty listening, following directions, knowing where there body is in space, and initiating movement. SS/C describes children who seek out high intensity or increased duration of sensory stimulation. They have behaviors such as constantly being on the move, falling down or crashing into people or the floor, staring at optical interests for an extended time period, or craving touch so much that they are in everyone else's space and face continually in an effort to gain more sensory information. Identification of SMD/SPD is only made when the resulting behaviors significantly affect a child's daily life (Bar-Shalita, Vatine, & Parush, 2008; Parham & Johnson-Ecker, 2000).

The overlap of symptoms in children with SMD and ADHD makes it difficult to differentiate the two disorders. For example, children with SMD who are SS/C often have attentional difficulties, poor impulse control, and hyperactivity (Mulligan, 1996; Smith Roley, 2006). Likewise, children with ADHD may have sensory symptoms characteristic of SMD (Ahn et al., 2004). For example, problems with sensory-over-responsivity (Barkley & Murphy, 1998; Lucker, Geffner, & Koch, 1996), especially in the somatosensory system (Castellanos et al., 1996; Parush, Sohmer, Steinberg, & Kaitz, 1997, 2007; Reynolds & Lane, 2008, 2009; Shochat, Tzischinsky, & Engel-

Yeger, 2009) have frequently been reported in children with ADHD. Additionally, some behavioral descriptors for ADHD and SMD are strikingly similar. SS/C and ADHD/HI both include poor impulse control, inappropriate movement and touch; sensory over-responsivity and ADHD/I both include behaviors such as distractibility and difficulty focusing; and sensory under-responsivity and ADHD/I both include being unaware when spoken to or asked to follow directions.

Although some behavioral characteristics of ADHD and SMD overlap, we hypothesize that the physiological reactions to sensory stimuli differs between children with ADHD and those with SMD. Sympathetic markers of nervous system function, assessed using electrodermal activity (EDA), have been used to characterize ‘‘flight or flight’’ reactions of children with SMD in response to sensory stimuli (McIntosh, Miller, Shyu, & Hagerman, 1999). EDA evaluates the skin's electrical conductance associated with changes in eccrine sweat gland activity in reaction to novel, startling or threatening stimuli, aggressive or defensive feelings (Fowles, 1986), and positive and negative emotional events (Andreassi, 1986). EDA includes measures of arousal (e.g., tonic skin conductance level), and reaction to stimuli (e.g., phasic skin conductance responses). Children with SMD are reported to exhibit large EDA responses to sensory stimuli, suggesting stronger physiological reactivity compared to typically developing children (McIntosh, Miller, Shyu, & Hagerman, 1999; Miller, Reisman, McIntosh, & Simon, 2001).

EDA has also been used to characterize children with ADHD. Early studies suggest that children with ADHD show smaller phasic reactivity to stimuli compared to typically developing children (Rosenthal & Allen, 1978; Spring, Greenberg, Scott, & Hopwood, 1974; Zahn, Abate, Little, & Wender, 1975). However, recent research suggests a disagreement remains as to whether the physiological reactivity of children with ADHD is smaller (Mangeot et al., 2001; Shibagaki, Yamanaka, & Furuya, 1993) or the same (Herpertz et al., 2003) as typically developing children. Likewise, studies differ on whether tonic arousal is lower in ADHD children (Beauchaine, Katkin, Strassberg, & Snarr, 2001; Lawrence et al., 2005; Lazzaro et al., 1999; Shibagaki & Yamanaka, 1990) or similar (Pliszka, Hatch, Borcherding, & Rogeness, 1993; Rapoport et al., 1980; Satterfield, Schell, Backs, & Hidaka, 1984) to typically developing children. It is likely that variability between studies, especially differences among the ADHD samples contributed to the inconsistent findings.

Thus, the need exists to differentiate ADHD from SMD both behaviorally and physiologically. This study sought to evaluate areas that may discriminate and overlap the two conditions using subjective measures of behavior as well as objective physiological measures of sensory reactivity to a variety of sensory stimuli. A sample of children with documented clinical diagnoses of ADHD, SMD, or a dual diagnosis of both, were evaluated for the presence of sensory sensitivities and for atypical attentional behaviors using parent-report measures. The association between clinician's diagnoses and identification of ADHD, SMD, or both based on results of parent-report measures were also evaluated. Additionally, electrodermal activity measured physiological reactivity to sensory stimuli.

Methods

Participants

A total of 176 participants were included in this study: 70 children with SMD, 37 children with ADHD, 12 children with a diagnosis of both SMD and ADHD, and 57 typically developing children. Children were referred to the Sensory Treatment And Research (STAR) Center, which was located at The Children's Hospital of Denver. Based on global clinical impression after extensive clinical observations during standardized tests of sensory and motor skills, extensive clinical observations in an OT gym, and parent interviews, expert occupational therapists referred children identified as having SMD (70 children).

Clinicians (psychologists, psychiatrists, and developmental pediatricians) who specialize in and regularly diagnose ADHD and treat ADHD, referred children with a clinical diagnosis of ADHD (37 children). Referral sources were the Child Development Unit at the Children's Hospital of Denver, the Child Study and Developmental Neuropsychology Clinics at the University of Denver, and the Attention and Behavior Center in Denver. Twelve children referred for either SMD or ADHD had documented diagnoses of the other (Dual Referral group). Children with diagnoses of fragile X, autism, mental retardation, Tourettes, Down syndrome, orthopedic conditions, bipolar disorder, depression, anxiety or other psychiatric diagnoses were excluded from the study.

Fifty-seven healthy children were selected from a pool of typically developing children, which included children of staff and volunteers of the Children's Hospital of Denver and other interested parents in the Denver area. None had traumatic birth history, unusual medical conditions, atypical educational, developmental, or traumatic life events. All had normal intelligence and demonstrated age-appropriate behavior and learning ability as reported by their parents.

All procedures were approved by the Institutional Review Board of the University of Colorado Denver.

At the time of enrollment in the study, the following medications were prescribed to the children: methylphenidate (2 SMD, 8 ADHD, 2 Dual Referral); methylphenidate and prednisone (1 ADHD); methylphenidate and clonidine (1 SMD); dextroamphetamine (4 ADHD, 1 SMD, 1 Dual Referral); dextroamphetamine and spirnolactone (1 SMD); dextroamphetamine and clonidine (1 ADHD); dextroamphetamine and sertraline (1 ADHD); fluoxetine (1 ADHD); sertraline (1

ADHD); albuterol and beclomethasone (2 SMD, 1 TYP); albuterol and Singulair (1 SMD). Parents agreed to have children miss stimulant medication from the evening before physiological testing until after the laboratory was completed, since previous studies demonstrated that stimulants have an effect on electrodermal activity (Hagerman et al., 2002; Lawrence et al., 2005).

Instrumentation

One parent of each participant completed four parent report measures. One scale focused on parents' perception of their child's responses to sensory stimuli and three scales evaluated parents' perception of attentional, hyperactive and/or impulsive behaviors in their child. All four measures were given to parents of all individuals, including parents of typically developing children to confirm that there were no indications of sensory, hyperactivity, impulsivity, or attentional problems.

Short Sensory Profile (SSP)

The SSP (McIntosh, Miller, Shyu, & Dunn, 1999) is a reliable and valid parent report measure of behaviors associated with atypical responses to sensory stimuli. The SSP was developed from the pool of items in the Sensory Profile (SP); a norm- referenced questionnaire that has 125 items (Dunn, 1999). Since emotional and fine motor domains were included in the original SP and 51% of the SP items did not load on factors, content analysis, item analysis, and factor analysis were undertaken to create a shorter tool (38 items) that focused only on sensory responsivity (McIntosh, Miller, Shyu, & Dunn, 1999). The SSP has a stable factor structure. There are seven subtests. Four subtests measure aspects of sensory over- sensitivity: Tactile Sensitivity, Movement Sensitivity, Auditory/Visual Sensitivity, and Taste/Smell Sensitivity. The Auditory Filtering subtest relates to screening out sensory information. The Sensory Seeking subtest is related to craving more than usual stimulation. The Low Energy/Weak subtest relates to sensory under-responsivity in the proprioceptive and vestibular sensory domains.

SNAP-IV

The Swanson, Nolan, and Pelman, version IV scale (Swanson, 1992) is an 18-item norm-referenced parent rating scale for the assessment of ADHD. The SNAP-IV is one of the most frequently used diagnostic tools for inclusion and exclusion in ADHD studies and was used in the NIH Multi-site Trial (Firestone, Musten, Pisterman, Mercer, & Bennett, 1998; Hinshaw et al., 1997; Jensen et al., 2001; Newcorn et al., 2001; Olvera et al., 2001). ADHD DSM-IV criteria are included in two subscales: inattention (items 1–9), and impulsivity (items 10–18). Sensitivity and specificity are greater than 0.94 in distinguishing children with and without ADHD (Zolotar & Mayer, 2004).

Leiter international performance scale—revised, parent rating subscales

Leiter-P rating scales (Leiter-P; Roid & Miller, 1997) items were derived from literature on child psychopathology, temperament, and personality theories and mapped directly onto DSM-IV criteria (Stinnett, 2001). Subtests measure parents' perception of their children's cognitive, social, emotional and sensory functioning. Items for attention, activity level, and impulsivity subscales were mapped on DSM-IV criteria for attention deficit disorders with and without hyperactivity.

Child Behavior Checklist (CBCL)

The CBCL (Achenbach, 1991) is a parent report scale that assesses a variety of behaviors. It provides information about a child's activities, social interactions and basic psychological behaviors. It is widely used, and its construct, content, and criterion validity are well established (e.g., Chen, Faraone, Biederman, & Tsuang, 1994; Elliott & Busse, 1991; Jensen, Watanabe, Richters, & Roper, 1996; Macmann et al., 1992; Mooney, 1984). CBCL subtests include withdrawn, somatic complaints, anxious/depressed, social problems, thought problems, attention problems and aggressive and/or Delinquent Behavior.

Physiological measures

Physiological reactions to sensory stimuli were measured by electrodermal response (EDR) during the Sensory Challenge Protocol (McIntosh, Miller, Shyu, & Hagerman, 1999; Miller et al., 1999). Fifty sensory stimuli (3 s each, pseudorandom 15– 19 s inter-trial interval) are presented in ten contiguous trials in each of five sensory domains (Olfactory, Auditory, Visual, Tactile, and vestibular). Sensory stimuli include: wintergreen extract, 90 dB siren, 10 Hz 20-W strobe light, a feather lightly moved from right ear to chin to left ear, and tipping the chair slowly backwards 30°.

Electrodermal activity was recorded throughout the session. Autogenics 5-mm diameter electrodes were applied to the palmar surface of the second and third distal phalanges of the right hand and secured using a Velcro band. Electrodes were attached to a Coulbourn Isolated Skin Conductance Coupler (S71–23, Allentown, PA, USA, Coulbourn Instruments), which applied a constant 0.5 V potential across the electrode pair and conditioned the signal. EDRs were assessed using changes in skin conductance associated with the presentation of stimuli (Miller et al., 1999). Since the measure of interest was the reaction to each stimulus (EDR) rather than changes in the slower fluctuating tonic skin-conductance level, alternating current (AC) coupling, which corrects for drifts in baseline conductance level over the extended time of stimuli presentation (Boucsein, 1992) was used. EDR signals were recorded at a sample rate of 1000 Hz, digitized and stored in computer files.

A data analyst blind to group membership checked the electrodermal records for movement artifacts and eliminated questionable responses using a custom written computer program (KIDCal; McIntosh, Miller, Shyu, & Hagerman, 1999; Miller et al., 1999). Peak amplitude was measured from the point at which the skin conductance increased sharply (baseline) to the point at which conductance began to fall (peak). Only peaks greater than 0.05 mS and beginning between 0.8 and 5 s post-stimulus were considered valid peaks (Dawson, Schell, & Filion, 1990).

Mean peak magnitude of the response to each stimulus type was used to describe the physiological responses measured by electrodermal activity. In computing the mean magnitude of response to each stimulus type, cases of non-response (i.e., no response after presentation of a stimulus) were included. When multiple responses occurred to a single stimulus, only the amplitude of the largest peak was used. Since magnitude data were positively skewed, a logarithmic transformation was applied to the data before analysis (Boucsein, 1992; Dawson et al., 1990). A value of 1 was added to all magnitudes before the transformation was performed, because the log of zero (a non-response) is undefined.

Identification of impairments based on parent report measures

Of the 119 children with a clinical referral (either for SMD, ADHD, or a Dual Referral), 71 children had data on all four parental report measures (SSP, SNAP-IV, CBCL, and Leiter-P). Data from these 71 children were used to evaluate how well the parent report measures identify clinical impairment of sensory (SSP), hyperactivity, impulsivity, and attentional problems (SNAP-IV, CBCL, Leiter-P) compared to the clinical diagnoses. On each measure, individuals were classified with impairment if their standardized score(s) met the cut point, defined as a score of two or more standard deviations from the normalized mean. Presence of sensory problems was based on a ‘modified SSP’, that is the SSP excluding the Sensory Seeking and Auditory Filtering subtests, because item content of these two subtests overlap to a great degree with items in the DSM-IV describing ADHD measures of attention and impulsivity. Hyperactivity, impulsivity, or attention problems were defined as present on the (1) SNAP-IV if either the hyperactivity/impulsivity or the inattention standardized score met the cutoff point, (2) Leiter-P if one of the attention, activity level, or impulsivity subscale standardized scores met the cutoff point, (3) CBCL if the attention subtest standardized score met the clinical impairment cut point. Since the number of individuals in the current study was relatively small, the three subtypes of ADHD (inattentive, hyperactive/impulsive, and combined) were collapsed and analyzed as one ADHD group.

Statistical analyses

The distribution of female and male participants and ethnic representation were compared across groups using chi- square tests. Age between the groups was compared with Analysis of Variance (ANOVA). Multivariate mixed model repeated measures ANOVAs were used to analyze raw subtest scores of the SSP, SNAP-IV, Leiter-P, and CBCL and to analyze EDR magnitude in five sensory domains. All initial analyses models included gender as a variable, since gender significantly differed between the groups (see Results). Gender only had an impact in the CBCL analysis (see CBCL Results). Since gender had no significant impact on the results in the SSP, SNAP-IV, Leiter-P, and EDR analysis, it was removed from these models. Age was used as a covariate in all analyses, since age significantly differed between groups (see Results). Significant interactions between subtest scores and referral group were followed up with independent mixed model analyses on each subtest to identify the particular subtest(s) on which the groups differed. After significant interactions and significant main effects were identified, post hoc pair-wise comparisons with Sidak adjustments for multiple comparisons were used to determine which groups differed from each other on a specific measure.

To assess the relationship between clinicians' diagnosis and parent ratings of sensory behaviors (based on the 'modified SSP' as described above) or parent ratings of ADHD behaviors (based on SNAP-IV, Leiter-P, or CBCL as described above) Pearson chi-square analyses with continuity correction for 2 X 2 tables were performed. Additionally, to quantify the proportion of agreement, Cohen's kappa statistic was determined for the diagnostic dichotomies (presence or absence of either sensory or ADHD behavior) for clinical referral compared to each individual parent report. In interpreting kappa, criteria proposed by Landis and Koch (1977) were used: scores of less than 0.20 are considered poor, scores between 0.21 and 0.40 are considered fair, scores between 0.41 and 0.60 are considered moderate, scores between 0.61 and 0.80 are considered substantial, and scores above 0.81 are considered near perfect agreement.

Results

In the sample of typically developing children, gender was approximately evenly distributed (49% female, 51% male). However, all three clinical groups (SMD, ADHD, Dual Referral) had significantly more male children (76% male SMD, 76% male ADHD, and 92% male Dual Referral; $X^2 = 13.82$, $p < 0.01$).

A majority of participants in the total sample of children (typical, ADHD, SMD, and Dual Referral) were Caucasian (89%). Also represented were African American (3%), Native American (1%), Hispanic (2%), Asian (3%), and other (2%) ethnicities. There were no significant differences between groups with respect to ethnicity ($p > 0.05$).

Average age significantly differed between groups ($F_{3, 172} = 16.46$, $p < 0.001$). Children with an ADHD referral were on average older (9.99 ± 2.26; mean ± SD) than children in all the other groups (SMD 6.79 ± 1.69, Dual Referral 7.78 ± 2.77, and typically developing children 8.09 ± 2.68; at least $p < 0.02$). Children with an SMD referral were significantly younger than ADHD and typical children ($p < 0.01$).

Questionnaire sample sizes vary since parents of some participants did not complete all measures. EDR measures had smaller sample sizes because not all participants participated in the physiological lab. Additionally, EDR participant data were excluded from analysis if it did not meet minimum quality standards or when all of the responses on the whole test failed to meet the minimum criteria for a response. These issues were due to either computer problems or poor electrode contact. The group in which there were absolutely no responses during the whole physiological lab may have included some children that are 'non-responders' or individuals that are able to sense the stimuli, but have no or extremely low physiological responses. Data from fifteen children were excluded because there were no responses meeting the minimum criteria for a response during the whole laboratory session: seven SMD, three ADHD, one Dual Referral, and four typically developing children.

Short Sensory Profile

There was a significant interaction between SSP subtest raw scores and referral group in the repeated measures (7 SSP subtests, 4 groups) mixed model analysis ($F_{21, 635} = 20.58$, $p < 0.001$). There was a significant main effect of referral group for every SSP subtest (Tactile $F_{3, 164} = 50.66$, $p < 0.001$; Taste/Smell $F_{3, 169} = 18.58$, $p < 0.001$; Visual/Auditory $F_{3, 164} = 45.75$, $p < 0.001$; Low Energy/Weak $F_{3, 169} = 19.14$, $p < 0.001$; Movement $F_{3, 169} = 14.43$, $p < 0.001$; Seeks Sensation $F_{3, 169} = 48.56$, $p < 0.001$; Auditory Filtering $F_{3, 169} = 84.85$, $p < 0.001$).

Children referred for SMD and those with a Dual Referral had significantly poorer raw scores compared to typically developing children on all SSP subtest scores ($p < 0.001$ and $p < 0.01$, respectively; Fig. 1). Children referred for ADHD had significantly poorer raw scores (at least $p < 0.01$) compared to typically developing children on all except Taste/Smell and Movement Sensitivity. Children with SMD had significantly poorer raw scores than children with ADHD (at least $p < 0.01$) on all except Seeks Sensation and Auditory Filtering. Children with a Dual Referral had significantly poorer raw scores compared to ADHD children ($p < 0.01$) and SMD children ($p < 0.02$) on the Seeks Sensation subtest. Children with a Dual Referral also had significantly poorer raw scores than ADHD children on Tactile, Visual/Auditory, Low Energy/Weak, and Movement subtests (at least $p < 0.05$).

Average standardized Z scores on the Seeks Sensation and Auditory Filtering subtests for all referral groups fell within the clinical impairment range (two or more standard deviations below the normalized mean of 0). Average Z scores on the Tactile and Low Energy/Weak subtests were in the clinically impaired range for children referred for SMD and those with a Dual Referral. The Visual/Auditory subtest average Z scores for children referred for SMD were right at two standard deviations below the normalized mean. No other average Z scores were within the clinical impairment range.

Figure 1

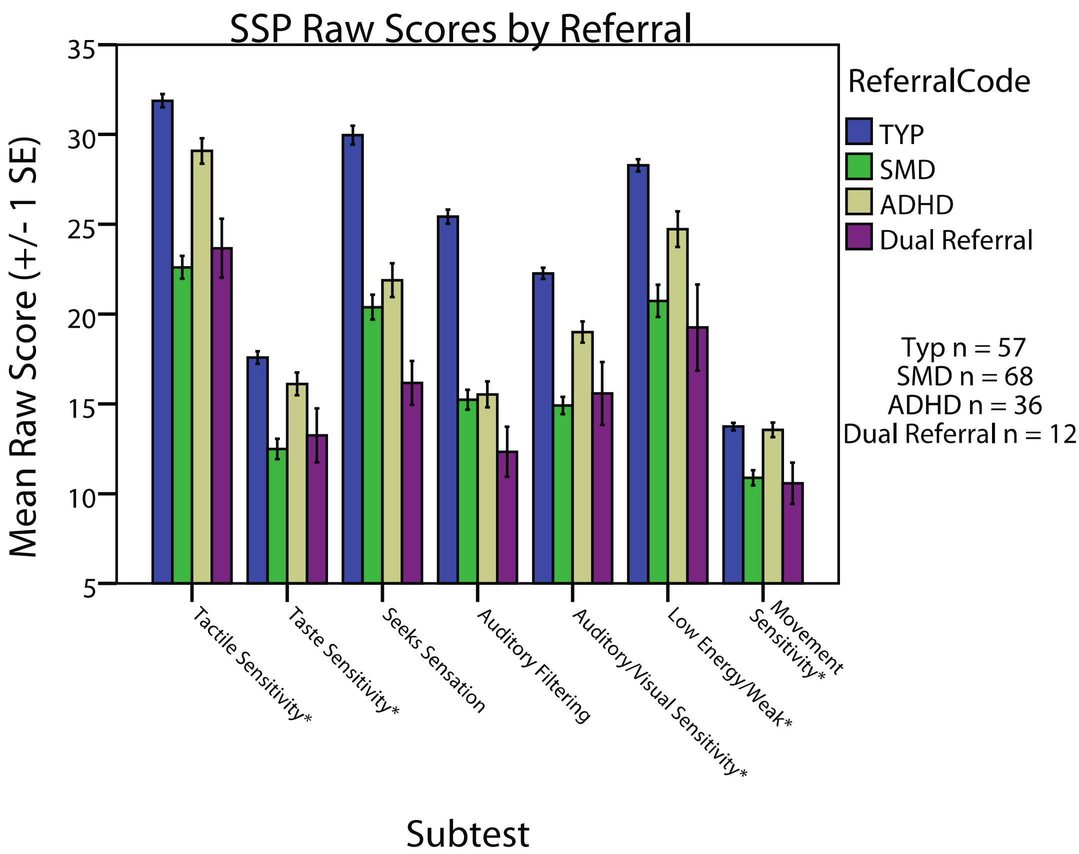

Figure 1: *Short Sensory Profile Raw Scores by Referral. SMD and Dual Referral groups were more impaired than typically developing children on all subtests of the SSP (p < 0.001 and p < 0.01, respectively). The ADHD group was more impaired than typical on all subtests (at least p < o.o1), except Taste/Smell and Movement Sensitivity. *The SMD group was more impaired than ADHD on all subtests (at least p < 0.01), except Seeks Sensation and Auditory Filtering.*

SNAP-IV

There was a significant interaction between the two SNAP-IV subtests (hyperactivity/impulsivity and inattention raw scores) and referral group in the repeated measures mixed model analysis ($F_{3, 290} = 5.78$, $p < 0.001$). There was a significant main effect of referral group for the hyperactivity/impulsivity subtest ($F_{3, 103} = 20.58$, $p < 0.001$) and for the inattention subtest ($F_{3, 103} = 58.78$, $p < 0.001$). Post hoc pair wise comparisons with Sidak adjustments revealed that all referral groups (SMD, ADHD, Dual Referral) had greater hyperactivity/impulsivity and inattention raw scores compared to typically developing children ($p < 0.001$; Table 1). Additionally, both ADHD and Dual Referral groups had significantly greater inattention raw scores than children referred for SMD ($p < 0.01$).

The ADHD and Dual Referral groups' average scores on the inattention subtest was in the range of clinical impairment, defined by a 5% cutoff score for parent report (i.e., above 1.78), whereas the SMD group average was within the normal range. The ADHD and Dual Referral groups' average scores on the hyperactivity/impulsivity subtest were also in the range for clinical impairment, defined by a 5% cutoff score for parent report (i.e., above 1.44). No average scores for the SMD and typically developing groups were within the clinical impairment range.

	SMD			**ADHD**			**Dual referral**			**Typical**		
Subtest	N	Range	Mean (*SD*)	N	Range	Mean (*SD*)	N	Range	Mean (*SD*)	N	Range	Mean (*SD*)
Hyperactivity /impulsivity	37	0.00-3.00	1.37 (*0.71*)*	28	0.11-2.78	1.49 (*0.81*)*[a]	12	1.00-2.78	1.87 (*0.60*)*[a]	30	0.00-1.56	0.43 (*0.40*)
Inattention		0.44-2.67	1.62 (*0.63*)*		1.00-2.89	2.00 (*0.40*)*#[b]		1.56-2.89	2.13 (*0.44*)*#[b]		0.00-1.56	0.50 (*0.38*)

Table 1: *Average Raw SNAP-IV Scores for All Participants.*

* Significantly different from Typical
# Significantly different from SMD
a- average Hyperactivity/Impulsivity score within range of clinical impairment, defined by 5% cutoff score (i.e., above 1.44)
b -average Inattention score within range of clinical impairment, defined by 5% cutoff score (i.e., above 1.78)
SMD = Sensory Modulation Disorder**;** **ADHD** = Attention Deficit Hyperactivity Disorder; **Dual Referral** = children with a clinical referral for both SMD and ADHD; **SD** = standard deviation.

Leiter-P

There was a significant interaction between the Leiter-P subtests (raw scores) and referral group in the repeated measures mixed model analysis ($F_{3,151} = 4.54$, $p < 0.01$). There was a significant main effect of referral group for every Leiter- P subtest (attention $F_{3, 151} = 57.08$, $p < 0.001$; activity $F_{3, 148} = 25.46$, $p<0.001$; impulsivity $F_{3, 147} = 31.08$, $p < 0.001$; adaptation $F_{3, 148} = 36.86$, $p < 0.001$; Mood and Confidence $F_{3, 151} = 21.93$, $p < 0.001$; Energy and Feelings $F_{3, 151} = 16.94$, $p < 0.001$; Social Abilities $F_{3, 149} = 21.20$, $p < 0.001$; Sensitivity and Regulation $F_{3, 149} = 28.63$, $p < 0.001$). All referral groups had significantly poorer raw scores compared to typically developing children on all Leiter-P subtests ($p < 0.001$). The Dual Referral group had significantly worse activity raw scores compared to the ADHD group ($p < 0.04$). The SMD group had significantly worse adaptation raw scores compared to the ADHD group ($p < 0.02$).

Average scaled scores for the Leiter-P activity, impulsivity, and Cognition subtests were near, but not quite within the clinical impairment range (defined as two or more standard deviations from the normalized mean), for children with a Dual Referral (Table 2). All other average scaled scores were within typical ranges.

	SMD			**ADHD**			**Dual Referral**			**Typical**		
Subtest	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)
Attention	**63**	2 – 10	6.08 (1.92)	**37**	2 – 9	5.00 (1.45)	**12**	2 – 6	4.67 (1.23)	**43**	5 – 10	9.19 (1.33)
Activity		2 – 10	6.29 (2.29)		2 – 10	5.97 (2.33)		2 – 7	4.25 (1.54)*		6 – 10	9.05 (1.36)
Impulsivity		1 – 10	5.48 (2.66)		1 – 10	5.05 (2.76)		1 – 10	4.25 (2.42)*		6 – 10	9.07 (1.20)
Adaptation		1 – 10	5.02 (2.45)		1 – 10	5.73 (2.94)		2 – 10	6.17 (2.76)		7 – 10	9.23 (1.04)
Mood & Confidence		2 – 10	5.94 (1.98)		3 – 10	6.11 (2.09)		3 – 10	6.25 (2.67)		7 – 10	9.40 (1.12)
Energy & Feelings		2 – 10	6.97 (2.18)		3 – 10	7.11 (2.11)		4 – 10	6.50 (2.35)		8 – 10	9.58 (0.82)
Social Abilities		2 – 10	6.63 (2.13)		2 – 10	6.41 (2.54)		2 – 10	6.33 (2.77)		7 – 10	9.40 (0.95)
Sensitivity & Regulation		4 – 10	6.32 (1.62)		4 – 10	6.68 (1.86)		4 – 10	6.67 (2.31)		7 – 10	9.51 (0.88)
Cognition		57 – 101	77.76 (9.98)		59 – 95	73.92 (8.65)		43 – 82	70.42 (9.77)		78–125	100.95 (11.30)
Emotional Regulation		67 – 99	80.10 (6.84)		70–103	81.54 (8.48)		71-100	82.33 (10.87)		85–119	103.21 (9.38)

Table 2: *Average Scaled Leiter-P Scores for All Participants. *Average scaled score within clinical impairment range, defined as two or more standard deviations below the normalized mean (normalized mean for Attention through Sensitivity & Regulation = 10, -2 SD = 4; normalized mean for Cognition and Emotional Regulation = 100, -2SD = 70);* ***SMD*** *= Sensory Modulation Disorder;* ***ADHD*** *= Attention Deficit Hyperactivity Disorder;* ***Dual Referral*** *= children with a clinical referral for both SMD and ADHD;* ***SD*** *= standard deviation.*

CBCL

There was a significant interaction between CBCL syndrome scale subtests (raw scores), referral groups, and gender in the repeated measures mixed model analysis (F21, 162 = 1.90, $p < 0.01$). To determine which referral groups differed from each other and on which subtests, independent mixed model analyses were conducted on each subtest with gender included in the model and age used as a covariate.

There were no significant effects of gender or interactions with referral groups in the withdrawn, anxious/depressed, Thought Disorders, or attention problems CBCL scales. There was a significant main effect of gender, such that females had greater reported impairment than did males in somatic complaints ($F_{1, 162} = 5.36$, $p < 0.02$) and social problems ($F_{1, 162} = 4.90$, $p < 0.03$).

There were significant main effects of referral group in withdrawn ($F_{3, 162} = 20.84$, $p < 0.001$), anxious/depressed ($F_{3, 162} = 25.26$, $p < 0.001$), Thought Disorders ($F_{3, 118} = 11.01$, $p < 0.001$), attention problems ($F_{3, 162} = 67.92$, $p < 0.001$), somatic complaints ($F_{3, 162} = 10.14$, $p < 0.001$), and social problems (F3, 162 = 41.31, $p < 0.001$) CBCL scales. Post hoc pair wise comparisons with Sidak adjustments revealed that all referral groups (SMD, ADHD, Dual Referral) had significantly greater impairments than typically developing children in the withdrawn ($p<0.05$), anxious/depressed ($p<0.01$), attention problems ($p < 0.001$), and social problems ($p < 0.001$) CBCL scales. ADHD referred children and SMD referred children had significantly more Thought Disorder problems compared to typically developing children ($p < 0.001$). SMD referred children and children with Dual Referrals demonstrated more somatic complaints compared to typically developing children ($p < 0.001$ and $p < 0.03$, respectively). Additionally, SMD referred children had more reported difficulties than ADHD referred children on the withdrawn ($p < 0.02$), anxious/depressed ($p < 0.003$), and somatic complaint ($p < 0.04$) CBCL scales.

There were significant interactions between gender and referral group in the Delinquent Behavior ($F_{3, 162} = 3.72$, $p < 0.01$) and Aggressive Behavior ($F_{3, 162} = 4.51$, $p < 0.01$) CBCL scales. Subsequent analysis revealed that for both Delinquent Behavior and Aggressive Behavior, males in all referral groups (SMD, ADHD, Dual Referral) had significantly greater reported difficulties than typically developing male children ($p < 0.01$ and $p < 0.001$, respectively). For females, those referred with SMD had significantly greater Delinquent Behavior and Aggressive Behavior scores compared to typically developing female children ($p < 0.05$ and $p < 0.001$, respectively). There was only one female with a Dual Referral, thus this group was excluded in the analysis of female Delinquent Behavior and Aggressive Behavior CBCL scores.

Average standardized T scores for all referral groups (SMD, ADHD, Dual Referral) on the attention problems scale were relatively at or very near the clinical impairment cut point (two standard deviations from the age-standardized mean of 50; Table 3). For all of the other CBCL subscales, all of the referral group's (SMD, ADHD, Dual Referral) and typically developing children's average T scores were within typical ranges.

	SMD			ADHD			Dual Referral			Typical		
Subtest	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)
Withdrawn	**67**	50– 91	63.21 (10.85)	**35**	50 –78	59.03 (8.32)	**12**	50 –70	58.08 (7.05)	**56**	50 – 68	51.23 (3.48)
Somatic Complaints		50– 95	63.19 (10.16)		50 –72	58.03 (7.92)		50 –75	59.50 (8.57)		50 – 78	53.70 (6.11)
Anxious/ Depressed		50– 90	64.15 (10.11)		50 –81	59.80 (8.87)		50 –74	62.67 (9.66)		50 – 63	51.38 (2.78)
Social Problems		50– 91	65.82 (10.16)		50 –77	62.51 (9.37)		50 –82	65.50 (10.05)		50 – 76	51.32 (4.2)
Thought Problems		50– 91	63.42 (8.41)		50 –76	61.29 (9.04)		50 –67	59.83 (7.16)		50 – 68	53.46 (5.19)
Attention Problems		50– 93	69.99 (10.34)*		57 –86	68.34 (7.53)		59 –86	70.33 (8.65)*		50 – 64	51.70 (3.52)
Delinquent Behavior		50– 73	57.63 (7.59)		50 –72	58.40 (6.75)		50 –73	59.67 (8.25)		50 – 67	52.00 (3.82)
Aggressive Behavior		50– 96	60.87 (10.04)		50 –75	60.89 (7.69)		50 –84	61.67 (12.14)		50 – 68	51.57 (3.88)
Withdrawn		50– 91	63.21 (10.85)		50 –78	59.03 (8.32)		50 –70	58.08 (7.05)		50 – 68	51.23 (3.48)
Somatic Complaints		50– 95	63.19 (10.16)		50 –72	58.03 (7.92)		50 –75	59.50 (8.57)		50 – 78	53.70 (6.11)

Table 3: *Average CBCL T Scores for All Participants. *Average T score within clinical impairment range, defined as greater than two standard deviations from the normalized mean (age-standardized mean = 50, +2SD = 70);* ***SMD*** *= Sensory Modulation Disorder;* ***ADHD*** *= Attention Deficit Hyperactivity Disorder****; Dual Referral*** *= children with a clinical referral for both SMD and ADHD;* ***SD*** *= standard deviation.*

Electrodermal Response Magnitude

The Dual Referral group was excluded from EDR data analysis because only six children participated in the physiological experiment. There was a significant interaction between sensory domain and referral group in the repeated measures (5 sensory domains) mixed model analysis ($F_{8, 126} = 3.42$, $p < 0.01$; Figure 2). For the Olfactory and Tactile domains, there were no significant main effects of referral group on the measure of EDR magnitude. There were significant main effects of referral group in the Auditory ($F_{2, 97} = 3.53$, $p < 0.03$), Visual ($F_{2, 96} = 9.08$, $p < 0.001$) and Movement ($F_{2, 95} = 6.36$, $p < 0.01$) domains. Post-hoc pair-wise comparisons with Sidak adjustments revealed that in response to auditory, visual, and movement stimuli the EDR magnitudes of SMD referred children were significantly greater than ADHD referred children and typically developing children (at least $p < 0.05$). In all sensory domains, there were no significant differences between ADHD and typically developing children.

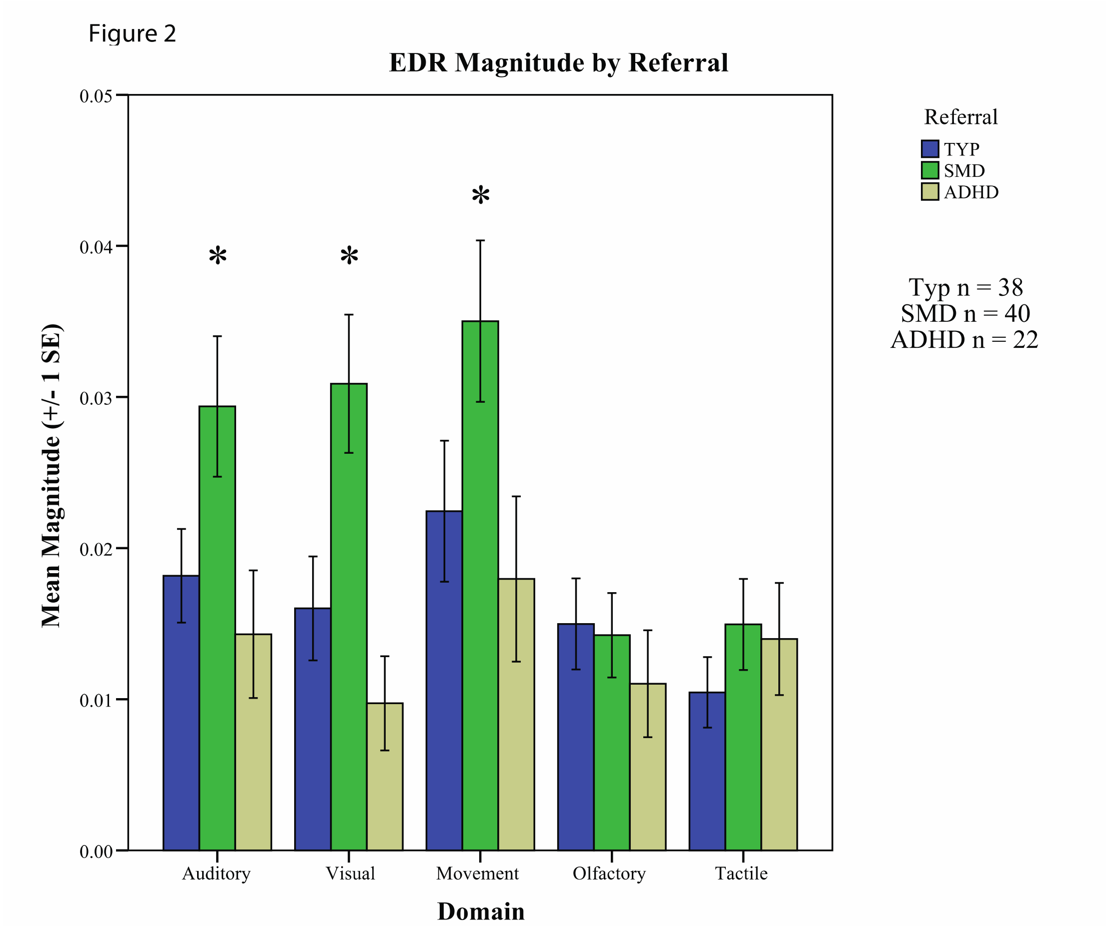

Figure 2. *EDR magnitude by Referral. EDR magnitudes in response to Auditory, Visual, and Movement stimuli were significantly greater in children referred with SMD compared to both children referred with ADHD and typically developing children (* at least p < 0.05). There were no significant differences between ADHD and typically developing children in any of the sensory domains.*

Identification of Impairments based on Parental Report Measures

The percent of children within each referral group that would have been misidentified if their diagnosis for sensory problems had been based on the 'modified SSP'(minus the Sensory Seeking and Auditory Filtering subtests), or diagnosis of hyperactivity, impulsivity, or attention problems, had been based on the SNAP-IV, Leiter-P, or CBCL rather than clinical judgments are shown in table 4. Pearson chi-square analysis revealed that the identification of individuals with sensory problems based on the 'modified SSP' was significantly correlated with clinical identification of SMD ($X^2 = 30.13$, $p < 0.001$). Agreement with respect to presence-absence of SMD between clinical referral and the modified SSP was 84.5% ($\kappa = .68$), suggesting substantial agreement. For each referral group less than 20% of children were misidentified with sensory problems (15% of children referred for ADHD) or misidentified lacking sensory problems (19% SMD and 8% Dual Referral).

The identification of individuals with ADHD based on the SNAP-IV was significantly correlated with clinical identification of ADHD ($X^2 = 6.31$, $p < 0.01$). Agreement with respect to presence-absence of ADHD between clinical referral and SNAP-IV was 66% ($\kappa = .28$), suggesting fair agreement. None of the Dual Referral group were misidentified and only 11% of the ADHD group were misidentified as lacking hyperactivity/impulsivity or inattention difficulties with the SNAP-IV. However, 66% of SMD referred children were misidentified as having hyperactivity/impulsivity or inattention difficulties based on the SNAP-IV parent report alone.

The identification of individuals with ADHD based on the Leiter-P was also significantly correlated with clinical identification of ADHD ($X^2 = 5.92$, $p < 0.02$). Agreement with respect to presence-absence of ADHD between clinical referral and the Leiter-P was 66% ($\kappa = .32$), suggesting fair agreement. The identification of individuals with ADHD based on the CBCL was not significantly correlated with clinical identification of ADHD ($X^2 = 0.99$, $p > 0.05$) and agreement between clinical referral was only 42% ($\kappa = 0$), suggesting poor agreement. Many children referred with ADHD or a Dual Referral were misidentified as lacking problems with activity, attention, or impulsivity when the parent report measures of the CBCL or Leiter-P were used. Additionally, many children referred for SMD alone were scored by their parent as having problems with hyperactivity, impulsivity, and/or attention based on the SNAP-IV, CBCL, or Leiter-P measures. Typically developing children were not included in these analyses since they were not clinically assessed. However, one typical child was misidentified on the SNAP-IV and none were misidentified on the SSP, CBCL, or Leiter-P measures.

Referral group	SMD	ADHD	Dual Referral	TOTAL
	N=32	*N=27*	*N=12*	*N=71*
Parent report measure				
SSP	19%	15%	8%	**16%**
SNAP-IV	66%	11%	0%	**34%**
CBCL	53%	67%	50%	**58%**
Leiter	38%	44%	0%	**34%**

Table 4: *Percent of Children Misidentified on Parent Report Measures of Sensory or ADHD – like behaviors. Note: only included children with complete data for all four parent report measures;* ***SMD*** *= Sensory Modulation Disorder;* ***ADHD*** *= Attention Deficit Hyperactivity Disorder;* ***Dual Referral*** *= children with a clinical referral for both SMD and ADHD.*

Discussion

In the current study, children with SMD significantly differed from children with ADHD on measures of sensation, emotion and attention as well as physiological reactivity to a variety of sensory stimuli. Specifically, based on parental report measures, children referred with SMD had more sensory problems, more somatic complaints, were more likely to be withdrawn or anxious/depressed, and had more difficulty adapting, but had fewer attentional difficulties than children referred with ADHD. Moreover, children referred with SMD exhibited greater physiological reactivity to a variety of sensory stimuli compared to both ADHD children and typically developing children.

Children with a clinical referral by an expert clinician for both SMD and ADHD (Dual Referral group) had significantly more sensory problems than did children with a clinical diagnosis of only ADHD. Thus, as expected significant sensory problems were noted in individuals with SMD as well as individuals who were diagnosed with both SMD and ADHD. However, similar to previous findings (Mangeot et al., 2001), sensory problems were also found in children referred with ADHD alone, who demonstrated significantly more impairment than typically developing children on the SSP in Tactile sensitivity, Visual sensitivity, Low Energy/Weak, Seeks Sensation, and Auditory Filtering. Indeed a high percentage of children with attention disorders also have sensory processing problems, exemplified by behavioral evidence of difficulty modulating sensory responses and over-responsivity (Cermak, 1991; Dunn, 1999; Miller et al., 2001; Parush et al., 1997). Often children with SMD are identified earlier than children with ADHD. In a retrospective study by Kaplan and colleagues (1994), sensory processing sensitivities are suggested to be apparent before attention, hyperactivity, or impulsivity problems as their particular ADHD sample was reported to have been overly sensitive in infancy to sensory stimuli and easily upset by environmental changes. Thus, the diagnosis of SMD may precede an ADHD diagnosis or suggest co-morbidity in some children. Together these studies and the current data suggest that children referred for ADHD should also be screened for SMD.

Sensory Differences

Two sections of the Short Sensory Profile, the Seeks Sensation and Auditory Filtering subtests, overlap with items in the DSM-IV describing ADHD. Thus, it is not surprising that children with ADHD and children with SMD, as well as those with a Dual Referral all had Seeks Sensation and Auditory Filtering problems. However, children with SMD were significantly more impaired on other subtests of the Short Sensory Profile than were children with ADHD, especially in the areas of Tactile Sensitivity, Taste/Smell Sensitivity, Visual/Auditory Sensitivity, Movement Sensitivity and Low Energy/Weak. Children with a Dual Referral were also significantly more impaired than were children with ADHD in the same areas except Taste/Smell Sensitivity. While these data suggest some overlap between the diagnoses of SMD and ADHD, children with SMD definitely have more sensory issues suggesting that these two groups are distinct diagnostic entities.

Attention, Activity, Impulsivity Differences

Children in all of the clinical referral groups had attention, activity, and impulsivity problems, as indicated by significant differences compared to typically developing children on scores of the Leiter-P, CBCL, and SNAP-IV measures. Although scores from these parent report measures did not indicate differences between children with SMD and children with ADHD on measures of activity and impulsivity, children with ADHD had significantly worse attention scores than children with SMD on both the Leiter-P and SNAP-IV measures, but not the CBCL. The observation that similar measures on different assessments did not all find differences between children with a clinical diagnosis of SMD compared to ADHD is common. Although, it has been suggested that symptom report by parent is an optimal strategy for identifying a child with ADHD (Hart et al., 1994), extensive questionnaires and rating scales that assess a wide variety of behavioral conditions, such as the CBCL, do not adequately differentiate between children with and without ADHD. Rather, ADHD-specific measures, such as the SNAP-IV, are more accurate (American Academy of Pediatrics, Committee on Quality Improvement and Subcommittee on Attention-Deficit/Hyperactivity Disorder, 2000). Children with SMD were differentiated from children with ADHD on the SNAP-IV Inattention subtest. Children with SMD had significantly fewer attentional problems compared to children diagnosed with ADHD, as well as compared to children with a Dual Referral. However, the SNAP-IV Hyperactivity/Impulsivity subtest failed to differentiate children with SMD from those with ADHD. This was not an unexpected finding as children with SMD, especially those with the Sensory Seeking/Craving subtype frequently present with similar behavior problems as children with ADHD. Children with this subtype of SMD tend to seek excessive amounts of movement and become overly excited by movement. While children with Sensory Seeking/Craving are hypothesized to be specifically seeking sensory input, children with ADHD are hypothesized to lack response inhibition. Behaviors such as impulsivity and hyperactivity may look similar, but we hypothesize that they are based on different neural mechanisms.

Emotional Differences

Children in all of the clinical referral groups also had emotional problems, as indicated by significant differences compared to typically developing children on all subtests of the Leiter-P and CBCL. Even though emotional symptoms were present and the clinical groups significantly differed from typically developing children, this does not unequivocally indicate that all children in the referral groups had clinically significant emotional impairments. Nonetheless, some emotional subtests did discriminate between children with SMD and ADHD. Children with SMD scored worse on behaviors related to adaptation or the ability to be flexible in the presence of unexpected occurrences, supporting the hypothesis that children with sensory abnormalities are more vulnerable to emotional problems (Miller et al., 2001). Specifically, children with SMD are thought to be more withdrawn and anxious because their environment is perceived as unpredictable and overwhelming. A lack of adaptation is a common compensation for the apparent feeling of lack of control over their daily sensory experiences, thus impairing their participation in purposeful, goal directed behavior (Dunn, 1997) and reducing participation in daily life activities and routines (Bar-Shalita et al., 2008).

Physiological Differences

Physiological reactivity to sensory stimuli also differentiated children with SMD from children with ADHD in the current study. Children with SMD exhibited greater electrodermal reactivity in response to auditory, visual, and movement stimuli compared to typically developing children, similar to previous studies (McIntosh et al, 1999b). Notably, children with SMD had greater electrodermal reactivity compared to children with ADHD. However, in contrast to a previous study (Mangeot et al., 2001), wherein children with ADHD had greater physiological responses to the first stimulus in each domain than did typically developing children, in the current study there were no differences in the magnitude of electrodermal reactivity between children with ADHD and typically developing children. Examination of individual trials was not possible in the current study because responses were collapsed across trials by the KIDCal program. In light of the finding by Mangeot and colleagues, evaluation of reactivity by trial is warranted in future studies.

The Mangeot study (2001) also had a large degree of variability within the ADHD sample, possibly due to a wide range of sensory sensitivities within the ADHD population studied. It is likely that the Mangeot ADHD sample may have consisted of children with ADHD alone and those with ADHD plus SMD. To correct for this in the current study and to identify more homogenous groups, a Dual Referral group was created that consisted of children with clinical diagnoses and referrals for both ADHD and SMD. Although it is possible that some children in either the SMD or ADHD group were not evaluated for both diagnoses, the samples in the current study are likely more homogenous than in previous studies.

Although it was not specifically evaluated in the current study, children with a Dual Referral may have greater physiological responses to stimuli compared to typically developing children. This hypothesis is based on the findings that children with SMD exhibit substantial electrodermal reactivity to stimuli (current study as well as McIntosh et al., 1999b) and children in the Dual Referral group were significantly more impaired than children with ADHD alone on most of the subtests of the SSP, which evaluates behaviors associated with extreme responses to sensory stimuli. Previous studies have shown that auditory-elicited electrodermal responses can differentiate children with comorbid ADHD plus conduct disorder from both children with ADHD alone and from typically developing children (Herpertz et al., 2001; Herpertz et al., 2003). Unfortunately, in the current study, physiological responses to stimuli in children with ADHD plus SMD were not compared to children in the other groups due to a small sample size of children with a dual referral. Although it is not yet known whether sensory-stimulus-elicited electrodermal responses can differentiate children with comorbid ADHD plus SMD from typically developing children or children with other disorders, the current data suggest that sensory-stimulus-elicited electrodermal responses may differentiate children with SMD from children with ADHD.

Identification of Impairments based on Parental Report Measures

Results from the current study suggest that some parent report measures are better than others in identifying sensory or attentional, hyperactive, and impulsive behavioral problems and in their agreement with the overall global clinical impression of an experienced clinician. In identifying sensory problems, the modified Short Sensory Profile (i.e., minus Seeks Sensation and Auditory Filtering subtests) correlated well with and had substantial agreement with the clinical identification of SMD. The overlap between the sensory seeking and auditory filtering subtests and ADHD behaviors suggest that the behaviors measured are similar and might be on an attention/impulsivity dimension rather than on a sensory dimension. Hence, those subtests should not be considered when trying to differentiate SMD from ADHD. Another weakness of the Short Sensory Profile is that it does not discriminate between Sensory Under-Responsivity and Sensory Seeking since items that measure each subtype are combined into a single score. Additionally, visual and auditory over-responsivity are combined into one subtest (3 visual items and 2 auditory items) and movement sensitivity has only three items. Currently there is no comprehensive sensory assessment that measures SMD (SOR, SUR, and SS/C) across all seven sensory domains (tactile, visual, auditory, smell, taste, vestibular, and proprioceptive). Thus, development of a scale that includes behaviors representative of all three subtypes of SMD (i.e., SOR, SUR, SS/C) is currently underway (Schoen et al., 2008). While the modified Short Sensory Profile did well in identifying sensory problems, parent report measures of attention, activity, and impulsivity were less likely to correspond to an ADHD clinical diagnosis. Although the CBCL did not exhibit significant agreement, the SNAP-IV and Leiter-P parent report measures exhibited fair agreement with clinical ADHD identification. The CBCL assesses a wide variety of behavioral conditions, including attention problems, whereas the Leiter-P and SNAP-IV are questionnaires in which items for attention, activity, and impulsivity are based specifically on the DSM-IV ADHD symptom list. Current results support the American Academy of Pediatrics suggestion that broadband questionnaires or rating scales, which assess many different behavioral conditions, such as the CBCL, should not be used for diagnosis of ADHD, but that ADHD-specific tests based on the DSM are an option in collecting evidence to establish a diagnosis of ADHD (American Academy of Pediatrics, Committee on Quality Improvement and Subcommittee on Attention-Deficit/Hyperactivity Disorder, 2000).

Although identification of presence or absence of ADHD based on SNAP-IV and Leiter-P scores significantly correlated with a clinician's ADHD diagnosis, the parental measures disagreed with clinical classification for 34% of the children. There are several possibilities for the lack of better agreement between clinical diagnosis and parent report measures for the presence or absence of ADHD. One possibility is that some children with a referral for SMD may not have been clinically evaluated for ADHD. Thus, some of the false positives for presence of ADHD in the SMD referred sample may actually have had ADHD. However, this is unlikely as physicians, who typically are the first to evaluate children, are more familiar with ADHD than SMD and many do not recognize SMD as a possible diagnostic category.

A second possibility is that some children may have had behavioral symptoms of ADHD at home, as indicated by the parental report measures, but the symptoms were not present in another setting. These children would not have met the DSM-IV diagnostic requirement that symptoms must be present in "two or more settings," and thus these children would not have been diagnosed with ADHD by a clinician. A limitation of the current study is lack of teacher report measures to confirm behavioral symptoms in a second setting and to corroborate the parent report measures. Although, many studies suggest that parents and teachers only partially agree on rating of a particular child's ADHD symptoms (Hartman et al., 2007; Sprafkin et al., 2002; Stefanatos and Baron, 2007; Willcut et al., 1999), some consensus exists that both provide different but valuable information about children's behaviors in different environments that consist of different tasks requirements or goals, different rules or expectations, and different attitudes, judgments and opinions about problematic behaviors. Barkley (2003) suggests that diagnosis of ADHD by parent report is sufficient, as it would probably be corroborated by teacher report, based on a study (Biederman et al., 1990) in which children identified with symptoms of ADD by parent report were also identified 90% of the time by teacher report. However, another study reported that parent ratings, but not teacher ratings on the Conners' ADHD-specific questionnaire were correlated with and predicted clinician's diagnosis of ADHD obtained during an unstructured clinical observation of behaviors (Edwards et al., 2005). Thus, parent and teacher reports exhibit wide variation in their agreement and there is no consensus whether it is best to use both parent and teacher reports together or one or the other in research studies. In the current study, inclusion of teacher reports may have helped to substantiate parent reports. Regardless, a diagnosis made by an expert clinician who evaluates all available information and gives a global clinical impression about the presence or absence of ADHD is considered the best assessment.

A third possibility, is that behavioral symptoms of ADHD were present in some children who did not receive a clinical diagnosis of ADHD because they did not fulfill one or more of the other three required diagnostic criteria: 1) symptoms persisted for at least 6 months; 2) some symptoms causing impairment need to have been present in some form before 7 years of age; and 3) evidence of clinically significant impairment in social, academic or occupational functioning. These three criteria need to be met in addition to having met the specific 6 of 9 symptoms criteria for inattention or hyperactivity-impulsivity (or both) and having symptoms in two or more settings to receive a diagnosis of ADHD according to the DSM-IV. Studies suggest there are variations in how rigorously and consistently clinicians adhere to DSM-IV criteria to make diagnoses (Faraone et al., 2003; Stein et al, 2004). Some clinicians may overlook a requirement, such as 'symptoms must be present in at least two settings', or may fail to verify requirements, for example functional impairment. Thus, some children may have been identified clinically with ADHD, but they did not reach the SNAP-IV and/or Leiter-P cut points for ADHD. Conversely, some children with behavioral symptoms of ADHD as identified by the parent report measures (SNAP IV and/or Leiter-P) may not have met all of the ADHD diagnostic criteria for a clinical diagnosis of ADHD, thus producing a lack of agreement between parent report measures and an ADHD referral.

A fourth possibility for lack of agreement between clinical diagnosis and parent report for the presence or absence of ADHD may be how children's behaviors were interpreted by either the parents or the clinicians. Data in this study suggests that there were two groups of children who were misidentified: 1) those who were identified by the parent as having ADHD, but were referred for SMD only and 2) those that were referred by a clinician as having ADHD, but whose parents did not agree. It is possible that parents of children in the first group did not understand the underlying sensory issues of their child and therefore categorized their behaviors as ADHD-like. In the second group, it is possible that the parent attributed their child's behavior problems to sensory issues even though the clinician made a diagnosis of ADHD. In

either case, a better understanding of the impact of sensory-related problems on behavior by both professionals and parents may help improve diagnostic accuracy.
Diagnostic guidelines recommend that a qualified clinician conduct a comprehensive examination and assessment of multiple sources of evidence before a diagnosis is made (Achenbach and Rescorla, 2004; American Academy of Pediatrics, Committee on Quality Improvement and Subcommittee on Attention-Deficit/Hyperactivity Disorder, 2000; Barkley and Murphy, 1998; Goldman et al., 1998; Pary et al., 2002). Behavior rating scales are widely used and frequently relied upon in diagnosing ADHD and SMD (e.g., Chan et al., 2005). However, the American Academy of Pediatrics recommends that behavior-rating scales be used as a supplement and not an alternative to clinical assessment (American Academy of Pediatrics, Committee on Quality Improvement and Subcommittee on Attention-Deficit/Hyperactivity Disorder, 2000). One review suggests that behavior-rating scales only agree about 50% of the time with clinician's diagnosis (Snyder et al., 2006). Thus, behavior-rating scales may best be used as a screening tool rather than as a replacement for clinical diagnosis. Improved assessment, especially the development of examiner administered scales and better integration of information from parents, teachers and healthcare providers would facilitate greater diagnostic accuracy and improve differentiation between ADHD and SMD (Arnold et al., 1997; Schoen et al., 2008).

Conclusion

The current study provides preliminary results suggesting that ADHD and SMD are separate dimensions and may be different diagnostic categories. Although co-morbidity does exist in some children with SMD and ADHD, individuals with attentional, hyperactive and/or impulsive issues without sensory problems and individuals with the converse appear to be separable. Children with ADHD significantly differed from children with SMD on measures of emotional, attentional, and sensory-related behaviors as well as physiological reactivity to sensory stimuli.
Differentiation of ADHD and SMD has critical treatment implications. While both clinical disorders impair social, academic or occupational functioning, children with ADHD typically benefit from medication (Benner-Davis and Heaton, 2007; Chavez et al., 2009; Findling, 2008; Soileau, 2008) or therapies that focus on cognitive strategies to improve attention, hyperactivity and impulsivity (e.g., Kaiser et al., 2008; Munoz-Solomando et al., 2008; Rader et al., 2009). Whereas, children with SMD benefit from Occupational Therapy using a sensory-based approach (Koomar and Bundy 2002; Miller et al., 2007), which enhances a child's ability to modulate behavior in response to the ever changing sensory environment and to participate more fully in activities at home, school and in the community.

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