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Sensory Processing in Children with ADHD: A Classroom Study and Rational Item Analysis

Jason Mathison
Philadelphia College of Osteopathic Medicine, jasonma@pcom.edu

Philadelphia College of Osteopathic Medicine

Department of Psychology

SENSORY PROCESSING IN CHILDREN WITH ADHD: A CLASSROOM STUDY AND RATIONAL ITEM ANALYSIS

Jason Mathison

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Dissertation Approval

This is to certify that the thesis presented to us by JASON Mathison

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Committee Members' Signatures:

George McCloskey, PhD, Chairperson

Lisa Hain, PsyD

Dr William Young

Robert A DiTomasso, PhD, ABPP, Chair, Department of Psychology

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Abstract

In the classroom, distinguishing between sensory modulation disorder (SMD), one proposed subtype of Sensory Processing Disorder, and attention deficit hyperactivity disorder (ADHD) can be difficult given their similar behavioral manifestations. The overlap between these two disorders and the prevelance of rating scales used for gathering diagnostic information warrant a closer look at items on commonly used rating scales to ensure discriminative validity. This pilot study examined specific patterns of SMD in 24 children with ADHD using the Sensory Profile School Companion (SPSC), which includes four components of SMD, namely, Seeking, Avoiding, Registration, and Sensitivity. As hypothesized, the majority of teacher ratings produced scores in the "Definite Difference" range within the Seeking (SS), Registration (SUR), and Sensitivity (SOR) quadrants; however, the majority of children were not rated as having a Definite Difference on the Avoiding quadrant. An item analysis revealed that items comprising Seeking, Registration, and Sensitivity appear too similar to items on commonly used ADHD rating scales and *DSM-IV-TR* criteria for teachers to behaviorally differentiate ADHD from SMD using this scale; however, items comprising the Avoiding quadrant were unique from those on ADHD rating scales and 33% of the sample were rated as having a Definite Difference in this area. The findings in this study lay the foundation for a more comprehensive study.

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CHAPTER 1

Introduction

Statement of the Problem

Attention deficit/hyperactivity disorder (ADHD) is one of the most common psychiatric disorders diagnosed in childhood. With a conservative estimated prevalence rate between 3 and 7% of school-aged children (Spencer, Biederman, & Mick, 2007), there is a great need for understanding the constellation of symptoms these children present and the etiology of these symptoms in order to diagnose and intervene effectively in the school setting. Given that ADHD is diagnosed behaviorally, understandably many children can meet criteria for ADHD despite different etiologies. Children diagnosed with ADHD are thought to have a central deficit in response inhibition (Barkley, 1997a; Oosterlan, Logan, & Sergeant, 1998; Pennington & Ozonoff, 1996; Quay, 1997; Schachar, Tannock, & Logan, 1993), as well as motivational and state regulation deficits (Van der Meere, Borger, & Wiersema, 2010); however, the variability of symptoms within and across these core deficits is great. Early studies focused on the behavioral symptoms of ADHD along with theoretical explanations of the causes of ADHD but failed to explain fully why such great diversity of symptom presentation exists among children with ADHD. Current research is addressing physiological, genetic, and developmental factors in attempts to explain the heterogeneity of symptoms evident among individuals diagnosed with ADHD. Although unclear as to whether these studies address etiology or comorbid contributors to symptomatology, attempts to increase understanding of ADHD are likely to help clinicians better target interventions that can address the symptoms presented by a child diagnosed with ADHD.

Sensory-processing dysfunction is a physiological condition that may exacerbate symptoms of hyperactivity and impulsivity. Atypical sensory responding, such as difficulty organizing sensations from one's own body and the environment (Ayres, 1972) or difficulty regulating and organizing reactions to sensations in a graded and adaptive manner (Ayres, 1972; Parham & Mailloux, 1996; Royeen & Lane, 1991), is known also as sensory modulation disorder (SMD). SMD occurs in roughly 5% of the general population (Ahn, Miller, Milberger, & McIntosh, 2004) and is even more common in children with ADHD (Cheung & Siu, 2009). Though not necessarily associated with ADHD, SMD may contribute to maladaptive behaviors in the classroom.

In recent years, multiple studies have identified links between ADHD and SMD (Cheung & Siu, 2009; Dunn & Bennett, 2002; Mangeot et al., 2001; Yochman, Parush, & Ornoy, 2004). A distinct pattern of sensory symptoms, however, has not been established as a core deficit in ADHD, and is unclear as to whether SMD symptoms can be differentiated from other ADHD symptoms in the classroom. In the public school system, maladaptive symptoms must be observable by the classroom teacher to warrant intervention. Only Dunn (2006) has researched sensory processing strictly in an educational environment and found that teachers may be able to observe SMD symptoms in children with ADHD.

Given the behavioral nature of ADHD symptomatology both in diagnosis and in treatment, schools commonly use rating scales for gathering data (Barkley, 2006; Crystal, Ostrander, Chen, & August, 2001; Demaray, Schaefer, & Delong, 2003; DuPaul & Stoner, 2003; Shelton & Barkley, 1994). Ideally, rating scales should be used in conjunction with other diagnostic methods (NASP, 2005); however, school psychologists and pediatricians continue to rely heavily on rating scales as the primary tool for diagnosis (Demaray et al., 2003; Wolraich, Bard, Stein, Rushton, & O'Connor, 2010).

Rating scales also can be used to identify sensory-processing dysfunction (Ahn et al., 2004; Davies & Galvin, 2007). For example, the Sensory Profile School Companion (SPSC) is a rating scale completed by teachers that is intended to identify sensory-processing dysfunction (Dunn, 2006). If sensory-processing dysfunction represents a constellation of symptoms that often is exhibited by individuals diagnosed with ADHD, then the presence and frequency of these symptoms also should be assessed when gathering rating-scale data.

Despite their utility in diagnosing ADHD (Barkley, 2006), rating scales have weaknesses, such as source effects (Barkley & Murphy, 1998; DuPaul, 2003; Gomez, Burns, Walsh, & Moura, 2003), accuracy (source specific behavior; Gomez et al., 2003), and bias (Chang & Stanley, 2003; Hosterman, DuPaul, & Jitendra, 2008). Of particular concern are the psychometric properties of rating scales (Myers & Winters, 2002). Validity, which is the most important property of a rating scale, can take years to develop (AERA, APA, NCME, 1999; Myers & Winters, 2002). For example, if a rating scale attempts to make inferences about underlying physiologically based mental processes, then construct validity in particular must be strong to ensure that the intended construct is being perceived and measured as intended (Burns & Haynes, 2006).

This study will examine teacher ratings of the sensory-processing capacities of children diagnosed with ADHD to help to determine whether a sensory-processing-dysfunction rating scale can differentiate a unique constellation of symptoms that is associated with the diagnosis of ADHD from the symptoms typically addressed on ADHD rating scales. If teachers endorse items describing sensory-based behaviors that are separate from behaviors typically thought to represent ADHD symptomatology, then future approaches to classroom interventions may need to be adjusted to include more “bottom-up” approaches that address noncortical sensory thresholds (Dunn & Bennett 2002; Miller, 2006; Parham & Mailloux, 1996), in addition to the “top-down” cortical intervention approaches currently in use that emphasize improving self-management (Barkley, Murphy, & Fischer, 2008; Lambek et al., 2010).

Purpose of the Study

The purpose of this pilot study was to examine if children previously diagnosed with ADHD-Combined Type (ADHD-C) were perceived by teachers to manifest SMD in the classroom and if items used on the Sensory Profile School Companion (SPSC) rating scale enable the differentiation of sensory-based behaviors from other ADHD symptomatology. Such differentiation could result in greater understanding of the symptoms associated with ADHD and could pave the way for new approaches to classroom interventions. It was proposed that teacher responses on the SPSC would reflect high levels of modulation difficulties, such as overresponsivity, sensory seeking, and underresponsivity to sensory input in children previously diagnosed with ADHD since these response styles are associated closely with hyperactivity and impulsivity. A rational content analysis was used to investigate whether items used to determine atypical sensory responding can describe a unique constellation of symptoms that can be differentiated from ADHD symptomatology. Results of this study may help determine if teachers perceive additional sensory-driven symptomatology in the classroom. Secondly, the results of this study may determine if items on the SPSC have enough discriminative validity to represent a constellation of symptoms that, although often observed in children diagnosed with ADHD, are typically not included on rating scales used in the diagnosis of ADHD.

CHAPTER 2

Review of Literature

Theories of Core Dysfunction in ADHD

Currently, the symptoms of ADHD are most commonly viewed as the result of disturbances in executive functions (Doyle, 2006; Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Though definitions of executive functions have historically varied (Barkley et al., 2008; Eslinger, 1996), recent meta-analyses of studies examining the executive functions of individuals diagnosed with ADHD have supported the hypothesis that lack of inhibition is the core executive-function deficit demonstrated by these individuals during childhood (Doyle, 2006; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Willcutt et al., 2005) and remains the core deficit into adulthood (Boonstra, Kooij, Oosterlaan, Sergeant, & Buitelaar, 2010); however, at least one meta-analysis found deficits in spatial working memory as the most common deficit exhibited by individuals diagnosed with ADHD (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). Russell Barkley (1997a, 1998, 2000a, b) has been instrumental in conceptualizing ADHD primarily as a problem of lack of behavioral inhibition and not of attention per se. Barkley (1997a) views ADHD as a neurologically based disorder rather than as an environmentally based or character-based (i.e., the result of defective moral control of behavior) condition. Barkley's view on ADHD as a disorder of inhibition has brought into question the nature of ADHD and whether the subtypes of ADHD Predominantly Combined Type (C) and ADHD-Predominantly Inattentive Type (PI) are separate and distinct disorders from ADHD-Predominantly Hyperactive-Impulsive Type (PHI) (Milich, Balentine, & Lynam, 2001).

In addition to lack of inhibition, numerous studies point to other executive-function weaknesses in children with ADHD (Semrud-Clikeman, Pliszka, & Liotti, 2008). While Barkley (1997a) argued that lack of inhibition is the central deficit of ADHD and may be the cause of other weaknesses in executive functioning, children with ADHD nevertheless often have difficulty with the executive functions of planning, set shifting, and organization as well as working memory (Semrud-Clikeman et al., 2008; Oosterlaan et al., 1998; Tannock, 1998; Vance, Maruff, & Barnett, 2003; Barkley, 1997a; Pliszka et al., 2006; Semrud-Clikeman, et al., 2006). These kinds of cognitively oriented top-down processing views of ADHD have resulted in the development of some rating scales that deviate from the American Psychiatric Association's *Diagnostic and Statistical Manual of Disorders* 4th edition, text revision (DSM-IV-TR; 2000) criteria, such as the Brown Attention-Deficit Disorder Scales (BADDS) (Brown, 2001).

Beyond executive dysfunction as a major feature of ADHD, the literature also suggests that regulation of motivation plays a role in the expression of ADHD symptoms (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006). For example, Luman Oosterlaan, & Sergeant (2005) reviewed the impact of reinforcement contingencies on ADHD symptomatology and found that some studies showed that difficulties with response inhibition could decline following the introduction of incentives. Children with ADHD also tend to exhibit a preference for smaller immediate rewards over larger delayed rewards, also known as *delay aversion*; (Luma et al., 2005; Sonuga-Barke, Sergeant, Nigg, & Willcutt, 2008; Sonuga-Barke, Taylor, Sembi, & Smith, 1992). Bitsakou, Psychogiou, Thompson, and Sonuga-Barke (2009) further found that children diagnosed with ADHD not only prefer immediate reward over delayed reward, but also exhibit increased delay-related frustration. Solanto et al. (2001) found that delay aversion and inhibitory deficits were both contributors to ADHD but are separate processes. Sonuga-Barke (2005) proposed that these processes create a dual pathway model that is the outcome of two independent neural pathways leading to both poor inhibitory control and a motivational style subtype (Lambek et al., 2010). In addition, there may be other factors that moderate inhibition beyond motivation and executive functions. Van der Meere et al. (2010) illustrated that lack of response inhibition associated with ADHD could be connected with poor state regulation, which refers to an overall state of alertness of an individual (Van der Meere & Stemerdink, 1999). Poor state regulation may work in tandem with poor executive functions such that poor alertness and variable or poor reaction time can undermine responses required to inhibit on tasks, such as go/no-go, especially when the presentation rate of a stimulus is altered (Johnson, Nicol, Zecker, & Kraus, 2007).

Current conceptualizations of the mechanisms underlying ADHD including executive functioning, state regulation, and delay-aversion also may be viewed as top-down and bottom-up information-processing models. The cortical processing involved in the use of executive functions, including planning, set shifting, fluency, and direction of working memory, can be thought of as top-down processing (Sergeant, Geurts, Huijbregts, Scheres, & Oosterlaan, 2003). Executive control of attention and emotional and arousal regulation also are considered top-down processes, and some scholars define these processes as simply goal-directed behavior (Kane, Bleckley, Conway, & Engle, 2001; Sergeant et al., 2003). Conversely, bottom-up processing predominantly engages subcortical brain function. State regulation, for example, may reflect poor bottom-up processing caused by slower response initiation and response time that is not mediated by the frontal lobe (Borger & Van der Meere, 2000). Reactions to reward and punishment also are thought to involve bottom-up processing (Knutson, Adams, Fong, & Hommer, 2002; Sagvolden & Sergeant, 1998), but the literature is unclear as to whether delay is bottom-up, top-down, or some combination of the two (Sonuga-Barke, 2002). After evaluating the aforementioned ADHD core theories, Sergeant et al. (2003) concluded that from a neuropsychological perspective both bottom-up and top-down processing are likely to be contributing to the ADHD condition.

Despite their unique contributions to the understanding of ADHD, several studies suggest that executive dysfunction and motivational causal models are limited in their capacity to explain all aspects of ADHD. Neuropsychological studies of executive functions in ADHD do support deficits in inhibitory control; however, executive dysfunction as a whole, and inhibition in particular, may not be a necessary or sufficient condition for the expression of the disorder (Sergeant et al., 2003; Willcutt et al., 2005). For example, Nigg et al., (2005) demonstrated that in a combined analysis of more than 1,000 ADHD cases, deficits in inhibitory control were demonstrated by approximately only 50% of children diagnosed with ADHD, and for other types of executive-function difficulties, the percentages were even lower. Interestingly, Solanto et al. (2001) found that deficits in inhibition were associated only moderately with ADHD, as were deficits in delay aversion, but together these two factors correctly classified 90% of children with ADHD, highlighting that neither executive function nor delay aversion models are individually sufficient to account for neuropsychological findings in the study of children diagnosed with ADHD (Castellanos et al., 2006; Sergeant et al., 2003).

Alternative Physiological Contributors

Rather than looking at ADHD in terms of a singular pathway or a dual pathway causal models ADHD may reflect multiple, interacting behavioral and neural differences (Castellanos & Tannock, 2002; Sagvolden, Johansen, Aase, & Russell, 2005) and even multiple pathways within the frontal lobe (Zelazo & Muller, 2002). In particular, Zelazo and Muller (2002) distinguished between “cool” circuits, which are associated more with executive functions involved in cognition, primarily housed in the dorsolateral prefrontal cortex, and “hot” circuits, which are associated more with executive functions involved in affect and emotion primarily housed in the orbital and medial prefrontal cortex. This distinction may be supported by findings that children with greater difficulty in response inhibition, related to “hot” aspects of executive function, benefit more behaviorally from stimulant medication (assuming the appropriate dose is given) than do children diagnosed ADHD-PI (Hale et al., 2011). These results underscore not only the heterogeneity problem in ADHD, but also the importance of direct assessment methods in order to discern “true” ADHD from related problems (Hale et al., 2011).

In addition to the prefrontal cortex, which includes both “hot circuits” and “cold circuits,” neuroimaging studies within the frontostriatal regions have revealed both structural and functional abnormalities for individuals diagnosed with ADHD. Volumetric studies found prefrontal volume and cortical thickness reductions in children and adults with ADHD (McAlonan & Cheung, 2007; Steinhausen, 2009), as well as a delay in cortical maturation, particularly in the prefrontal regions (Shaw, Lerch, & Sharp, 2006). In fact, children with ADHD demonstrated developmental lags of as many as 3 years in cortical maturation (Shaw et al., 2007; Steinhausen, 2009). Beyond frontal circuitry, structural and functional findings using magnetic resonance imaging (MRI)s and functional magnetic resonance imaging (FMRI)s have revealed abnormalities, including total volume (Castellanos, Lee, & Sharp, 2002), decreases in grey matter (Brieber, Neufang, & Bruning, 2007), and decreases in cortical thickness (Shaw et al., 2006), within subcortical temporal lobe structures.

Dysfunction of the amygdala and hippocampus, structures that are involved in the processing of reward-related information (Elliot, Friston, & Dolan, 2000; Ernst, Bolla, & Mouratidis, 2002) also may play a role in the symptomatology of ADHD. The amygdala, in particular, plays a role in memory and emotional reactions. Frodl et al. (2010) found that individuals with ADHD with more hyperactivity and less inattention have smaller right amygdala volumes, which in part could explain the emotional dysregulation exhibited by these children with ADHD. Ludolph, Pinkhardt, and Tebart (2008) further found that amygdala volumes are smaller when ADHD cosymptomatology is more severe.

The hippocampus, on the other hand, encodes temporal relations between sensory experiences and plays an important role in modulation of sensorimotor experiences (Bast

& Feldon, 2003). In addition, the hippocampus plays an important role in the memory of sequencing of events (Fortin, Agster, & Eichenbaum, 2002). Plessen, Bansal, and Zhu (2006) looked at the morphology of the hippocampus in children with ADHD and found enlargements in the hippocampus (particularly the head) that were interpreted as a compensatory neuroplastic response to disturbances in time perception and temporal processing (Barkley, Koplowicz, Anderson, & McMurray, 1997). A meta-analysis of structural imaging studies also indicated consistent volumetric reductions in the cerebellum of children with ADHD (Valera, Faraone, Murray, & Seidman, 2007). Studies also implicate the reticular activating system (RAS), a system of nerve cells and brain stem structures extending into the midbrain, where lowered levels of RAS functioning might be implicated in ADHD resulting in state regulation difficulties (Kawamura, 2009; Satterfield & Dawson, 1971).

Of particular concern is dysfunction within the parietal regions. ADHD-related dysfunction may be found in somatosensory cortex involved in sensory-integration processing. The parietal lobe plays an important role in somatosensory processing and sensory integration, as well as has functional ties to inhibition and spatial working memory, all of which are implicated in core theories of ADHD. Studies of resting-state brain activity have reported hyperperfusion of the somatosensory areas in children with ADHD (Kim, Lee, & Shin, 2002) that could result in reduced inhibition in sensory areas, thus leading to sensory hyperarousal (Aston-Jones, Rajkowski, & Cohen, 1999). These results may help link sensory processing with ADHD at a cortical level.

Sensory Processing

Sensory-processing dysfunction, which entails difficulty organizing sensations from one's own body and the environment (Ayres, 1972), or difficulty regulating and organizing reactions to sensations in a graded and adaptive manner (Ayres, 1972; Parham & Mailloux, 1996; Royeen & Lane, 1991), is a complex disorder of the brain that affects children and adults. "*sensory integration*" is a term that was first coined by Jean Ayres (1972) as "the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment" (page 11). People with atypical sensory processing may display altered sensory thresholds compared to those of normal children (Dunn 1999), which may play an important role in overresponding and underresponding to environmental triggers. The terminology associated with sensory-dysfunction has varied (e.g., sensory-integration disorder, sensory-processing dysfunction, sensory defensiveness, tactile defensiveness), but a current nosology was proposed recently by a scientific work group formed by the Sensory Processing Disorder Foundation Research Institute, which included a multidisciplinary collaboration of leading scientists from university-based research institutions to examine the validity of Sensory Processing Disorder (SPD) as a unique and separate syndrome from other disorders. Using Pennington's model of syndrome validation (Pennington, 1991; Pennington, 2002), the scientists evaluated five areas that increase the likelihood that a syndrome exists: etiology, pathogenesis, signs and symptoms, treatment, and developmental course. In their latest revision (2008), the scientific work group addressed all areas of Pennington's model to suggest inclusion of

(SPD) in the DSM-V, which is currently being considered. They proposed three primary subtypes under this umbrella: Sensory Modulation Disorder (SMD), Sensory Based Motor Disorder, and Sensory Discrimination Disorder.

One of the biggest challenges that the scientific work group faces is demonstrating that SPD can occur independently of other syndromes. Estimated rates of sensory processing dysfunction for children with disabilities have ranged from 40% to as high as 88% (Ahn et al., 2004; Talay-Ongan & Wood, 2000) but there are few documented cases of individuals having SPD that would warrant intervention without meeting criteria for any other diagnosis. To date, only Reynolds and Lane (2008) and Carter, Ben-Sasson, and Briggs-Gowan (2011) have published studies of children meeting the criteria for sensory-processing dysfunction without meeting criteria for any internalizing or externalizing disability. Within the general population nearly 5-9% of all children experience some form of an SPD based on parent perceptions (Miller, Milberger, & McIntosh, 2004). Sensory-processing dysfunction not only occurs in almost all children and adults diagnosed with autism (Case-Smith, 2005), but also has been linked in the research to Tourette’s disorder, ADHD, fragile X, trauma and abuse, prenatal alcohol, prenatal stress effects, schizophrenia, and obsessive compulsive disorder (Ayres & Tickle, 1980; Baranek, 1999; Baranek & Berkson, 1994; Baranek, Foster, & Berkson, 1997; Cermak & Daunhauer, 1997; de Gelder, Vroomen, Annen, Masthof, & Hodiamont, 2003; Grandin, 1992; Kinnealey, 1973; Larson, 1982; Mangeot et al., 2001; Miller et al., 1999; Rieke & Anderson, 2009; Schneider et al., 2008).

Dunn's Model of Sensory Processing

Dunn's model of sensory processing proposes an interaction between neurological thresholds and behavioral responses (Dunn, 1997), which incorporates both bottom-up views of stimuli processing (neurological thresholds) and top-down views involving the management of needs and preference for information processing through self-regulation. This view accounts not only for differences in neurological thresholds, but also for differences in self-regulation strategies that individuals use to cope with their threshold.

Dunn's model proposes four sensory-processing patterns to account for differences in high versus low sensory thresholds, and active versus passive responses to thresholds: *Registration, Seeking, Sensitivity,* and *Avoiding*. Registration refers to a child with high neurological thresholds for sensory input and a passive self-regulation approach. These children may not detect sensory input and may fail to react. A Seeking pattern is also the result of a high neurological threshold, but these children have an active self-regulation strategy through which they may engage during class in self-stimulation behaviors, such as tapping their pencil or chewing on things, to get more of the sensory input they need. According to Dunn, a Sensitivity pattern consists of a low neurological threshold with a passive self-regulation strategy. These children may ask others to be quiet or put their hands over their ears. An Avoiding pattern represents a low neurological threshold as well, but uses active self-regulation strategies, such as avoiding activities and situations. These patterns of behavior stemming from the combination of neurological thresholds and self-regulation strategies are theoretically consistent with SMD (James, Miller, Schaaf, Nielson, & Schoen, 2011). Figure 1 aligns SMD subtypes proposed by Miller, Anzalone, Lane, Cermak, and Osten (2007) with Dunn's model of sensory processing (1997), the framework used in this study.

<table>
<tr><th>Dunn's Model (1997)</th><th>Proposed SMD Subtypes (Miller et al., 2007)</th></tr>
<tr><td>Registration</td><td>Sensory under-responsivity (SUR)</td></tr>
<tr><td>Seeking</td><td>Sensory Seeking/Craving (SS)</td></tr>
<tr><td>Sensitivity</td><td rowspan="2">Sensory over-responsivity (SOR)</td></tr>
<tr><td>Avoiding</td></tr>
</table>

Figure 1. SMD proposed subtypes.

SMD Subtypes

Under the umbrella of SPD, current nosology proposes that SMD consists of three subtypes: sensory overresponsivity (SOR), sensory underresponsivity (SUR), and sensory seeking/craving (SS) (Hanft, Miller, & Lane, 2000; Miller et al., 2007). These subtypes are not mutually exclusive and may be seen together in the same child. Parush, Sohmer, Steinberg, and Kaitz (2007) found that a large proportion of sensory seekers have ADHD with high thresholds, but interestingly 69% of boys with ADHD also demonstrate tactile defensiveness and can be classified additionally as having SOR. In fact, overresponders comprise 80% of referrals (Schaaf, 2001) and so much of the research on SMD has focused on SOR with ADHD. Children with SOR have responses to sensory stimuli that are faster, longer, or more intense than those expected with typical sensory responsivity (Miller et al., 2007). Individuals with SOR may have a sensory-processing pattern that includes Sensitivity or Avoiding, such as withdrawing from certain types of touch, covering their ears in response to everyday sounds, and/or avoiding movement activities that are typically enjoyable or innocuous to others. These individuals also may have limited diets because of sensitivity to the taste, smell, or texture of certain foods. They also may get overwhelmed easily in certain environments, demonstrate strong emotional reactions to sensory stimuli, and engage in disruptive behaviors when demands become too great (Parham & Mailloux, 2005).

Among the three SMD subtypes, only SOR is supported by research as occurring as a unique entity. Reynolds and Lane (2008) presented three case studies of children with SOR without a comorbid condition, and more recently, Carter et al. (2011) identified a far greater number of children with SOR without a comorbid condition using interviews and rating scales. Specifically, Carter et al. (2001) studied a sample of 338 children using parental responses on the Sensory Over-responsivity Inventory (SensOR) (Schoen, Miller, & Green, 2008) and found that the majority of children with SOR did not meet a *DSM-IV TR* (2001) child psychiatric disorder based on the Diagnostic Interview Schedule for Children, Version IV (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). However, given the behavioral approach used in this study (rating scales and interviews), future studies may need to include neurocognitive and neuroanatomical assessments to better understand the etiological underpinnings. Symptoms of SOR also may overlap behaviorally with anxiety. Differentiating SOR from anxiety, especially in the classroom setting, may be difficult. Ben-Sasson, Cermak, Orsmond, Carter, and Fogg (2007) conducted a survey study during which 25 psychologists and 24 occupational therapists completed a survey that rated various anxiety and sensory-processing disorder characteristics in toddlers. They found that psychologists more frequently attributed behaviors to generalized anxiety disorder, whereas occupational therapists more frequently diagnosed behaviors as SOR. The authors highlighted that many behaviors in young children are challenging to differentiate, particularly at early ages. Of greater importance may be determining if anxiety and SOR are different constructs with different etiologies. Green and Ben-Sasson (2010) explored three possible theories that could explain the association between SOR and anxiety. In consideration that anxiety causes SOR, threat-based emotion regulation (Craske, 2003) or hyperarousal for threat-relevant stimuli may contribute to an individual's overreactivity to sensory stimuli. If a child is hyperaroused and scanning the environment for threats, he or she is more likely to notice and react to sensory stimuli. Further, once reactivity to particular stimuli is established, then reactions may be maintained or exacerbated by classical aversive conditioning.

Considering that SOR causes anxiety, one could argue that an unpleasant bottom-up response to a stimulus (e.g. an aversive noise) resulting from differences in sensory gating may classically condition a fear of a sensory stimulus or create hyperarousal towards that stimulus. Another possibility is differences in pain perception. Bar-Shalita, Vatine, Seltzer, and Parush (2009) found that children with SOR in particular do not show overly sensitive detection ability but perceive more pain and that their pain lasts longer, thus suggesting greater central nervous system involvement. Just as differences in sensory gating may lead to anxiety, differences in pain perception also may drive anxiety to various stimuli. Finally, there is some evidence that SOR and anxiety are not related causally at all, but are associated through a third variable, such as the functioning of the amygdala. The amygdala has been implicated in anxiety disorders (Davis, 1992), but also may play a role in SOR. Zald (2003) reviewed several studies and found that the amygdala receives sensory input from auditory and visual sensory areas of the cortex, and unpleasant perceptions of those stimuli are correlated with amygdala activation. Lane, Reynolds, and Thacker (2010) found physiological differences in salivary cortisol and electrodermal responsivity to sensation in children diagnosed with ADHD. In fact, they found that 46% of children with ADHD had SOR. Further, they found that SOR, anxiety, and ADHD all can overlap or occur independently of one another.

In the context of the classroom only, Dunn (2006) performed a study to determine how useful the Sensory Profile School Companion (SPSC) is in identifying sensory processing differences in children with ADHD. Using a sample of 59 children with ADHD and a matched sample of students without disabilities, several classroom teachers rated students using the SPSC. Based on the Dunn's model (1997), SOR is comprised of a Sensitivity pattern (children with low neurological thresholds with passive self-regulation strategies) and Avoiding patterns (children with low neurological thresholds and active self-regulation strategies). According to Dunn, the distinction between children with active versus passive approaches to sensory input is important because each approach warrants different interventions. Dunn's study revealed moderate differences in Sensitivity, and a small effect for Avoiding; however, comorbidity was not addressed. The sample also included only six African American children.

Sensory underresponsivity (SUR) is characterized by absent or diminished responses to normal levels of sensory input. Children with SUR may be described as sluggish, apathetic, or clumsy and may be difficult to engage (Lane, Lynn, & Reynolds, 2010). Dunn (2006) found a small-to-moderate effect size in the Registration pattern, suggesting some difference in SUR between children with ADHD and the normal population.

Sensory seekers (SS) actively search for sensory input. These children may engage in self-stimulation behaviors, such as tapping on the desk, rocking in their chair, and recklessly bumping into things. SS in particular may be easily confused with ADHD because of the observable hyperactive behaviors. James et al. (2011) performed a cluster analysis based on four parent-report instruments and found that a seeking/craving subtype exists, but they noted considerable behavioral overlap with impulsive and hyperactive behaviors associated with ADHD based on the Short Sensory Profile (SSP) and *DSM-IV TR* (2000) criteria. James et al. (2011) also contended that the hyperactive and impulsive behaviors associated with SS are based on different neural mechanisms.

Interestingly, Dunn's (2006) study revealed no significant difference in SS behavior in children with ADHD compared to normal children. Dunn (2006) also found that the lowest correlation between home and parent forms was in this area (-.20). These results may suggest that SS problems are more noticeable by parents of children diagnosed with ADHD than by teachers. Dunn attributed this difference to the fact that parents see the child in many more unstructured settings than does the teacher.

Contributors to Sensory Processing

Little is known about the neurobiological substrates of SPD or the developmental precursors, but considerable research has been conducted in recent years. Schneider et al. (2008) examined the dopamine system in the striatum and its possible relationship to sensory-processing functions. Their findings suggest that one contributing factor to SPD may be alterations in the functioning of the dopaminergic regulatory systems caused by stress and prenatal alcohol consumption; however, dopamine measurements were made only in the striatum. Future studies will need to evaluate dopamine in the prefrontal cortex and nucleus accumbens. Using primates, this study was the first to induce stress and alcohol to link atypical or poorly modulated sensory processing. This supports the notion that there are likely prenatal and environmental contributors to sensory dysfunction in people. Atchison (2007) found similar results in that children who experienced both trauma and/or fetal alcohol spectrum disorder had sensory-modulation difficulties. Crepeau-Hobson (2009) further showed that early neonatal status and prenatal and birth/delivery were also strong factors in predicting future sensory problems based on responses to the SSP.

In looking beyond prenatal care, there is also evidence that children who lack physical contact are at greater risk of sensory-processing dysfunction. Cermak and Miller (2005) examined the length of institutionalization of adopted children, a group particularly at great risk for prenatal, perinatal, and developmental problems. They found that children who had been institutionalized longer than 18 months had more atypical sensory integration and modulation problems than did children who were adopted at only 6 months. Wilbarger, Gunnar, Schneider, and Pollak (2010) found similar results in that children who were adopted after being institutionalized for longer than 12 months had higher levels of reactivity to sensory input compared to those of children adopted after fewer than 8 months. Taken together, both studies suggest that poor environment, low contact, poor nutrition, and abuse may exacerbate sensory- processing problems.

In addition to sensory gating, there may be marked differences in the sympathetic nervous system of children with SMD. McIntosh, Miller, Shyu, and Hagerman (1999) and Miller et al. (1999) utilized the Sensory Challenge Protocol, which evaluates autonomic nervous system function with electrodermal activity, and demonstrated that children with SMD have marked differences in overresponsivity and underresponsivity compared to normal subjects (McIntosh et al., 1999; Miller, Reisman, McIntosh, & Simon, 2001; Miller et al., 1999). Their results provided compelling evidence that within the autonomic nervous system, the sympathetic branch, which modulates immediate responses to events such as fight-or-flight reactions, account for much of the overreactivity in behaviors of children with SMD. Schaaf et al. (2010) used the Sensory Challenge Protocol to look further at parasympathetic activity, which modulates the visceral and neuroendocrine systems to maintain homeostasis (rest and digest activities). Based on Porges' (1995, 2001, & 2007) polyvagal theory, which describes the potential relationship between parasympathetic activity and behavioral adaptability, their hypothesis was supported that the parasympathetic nervous systems of children exhibiting SMD symptoms were unsuccessful in regulating responses to stimuli from the sensory challenge thereby resulting in atypical behavioral responses.

While studies by McIntosh et al. (1999) and Miller et al. (1999) support differences in autonomic activity in children with SMD, there are important limitations to consider. First, both studies need to be replicated with a greater number of subjects.

Secondly, one study did not control for gender. If, indeed, females have weaker gating than males (Hetrick et al., 1996; Patterson et al., 2008; Waldo, Graze, de Graff Bender, Adler, & Freedman, 1987; White, Kanazawa, & Yee, 2005), it is not clear if this difference would manifest on the Sensory Challenge Protocol as it did on other studies using the P50, N100, and P200. Of greatest importance is the fact that children with the more severe SMD symptoms demonstrated significance in sensory gating. Despite these findings, the question still remains as to the point at which these sensory-related behaviors are noticeable to teachers in the classroom and to what degree environmental factors play in SMD.

In support of the premise that the central nervous system plays a role in sensory processing, Bar-Shalita et al. (2009) found that children exhibiting the overresponsiveness form of SMD do not show overly sensitive detection ability but express an increase in responsivity to painful stimuli. Along with differences in the autonomic nervous system, there may indeed be physiological differences between children with SMD and ADHD. However, it is important to note that the role of the central nervous system may be overestimated in SMD. Koziol, Budding, and Chidekel (2011) have proposed an integrative and interactive model involving the neocortex, basal ganglia, and cerebellum. Rather than looking at response to sensory input linearly in a single pathway from perception to action, their model is more ethologically oriented and places greater emphasis on multiple pathways involving these cortical and subcortical structures.

Sensory Processing Versus Executive Functioning

Children with SMD demonstrate executive-function problems similar to those observed in children diagnosed with ADHD. For instance, common manifestations of SMD include distractibility and impulsivity (Mangeot et al. 2001; Ognibene, 2002; Parham & Mailloux, 1996). While children with SMD may have differences in sensory gating and autonomic nervous system responses (Davies, Chang, & Gavin, 2009), those studies have not determined if these physiological processes associated with SMD are distinct from ADHD. Ognibene (2002) attempted to distinguish SMD from ADHD using sensory habituation and response inhibition tests. He found that children exhibiting SMD symptoms did not habituate to repeated sensory stimuli, unlike children diagnosed with ADHD, who did. He also found that children with ADHD-C demonstrated poorer inhibition skills on go-no-go trials, whereas the group exhibiting SMD symptoms performed much better. These opposing profiles indicated that although both groups share similar behavioral features, there is evidence that ADHD and SMD may represent distinctly different underlying etiologies.

Despite these differences, most of the deficits of both groups may stem from a failure to efficiently engage top-down control processes rather than an inability to implement bottom-up filtering in sensory-processing areas (Friedman-Hill, Wagman, Gex, Pine, Leibenluft, & Ungerleider, 2010). Specifically, Friedman-Hill et al. (2010) conducted an experiment in which distracter salience and perceptual decision difficulty were manipulated to evaluate attentional filtering abilities. In their study, they found that children with ADHD had difficulty filtering out distracters on trials with easy discriminations and low salience distracters, yet counterintuitively, they did better on tasks with greater interference and salience. Friedman-Hill et al. further posited that if sensory competition underlies distractibility, then distractibility would increase linearly with sensory input. Given the opposite was the case, the findings supported a top-down (cortical) rather than a bottom-up (subcortical) view of attentional filtering.

Casey (2001) proposed that disruptions in the basal ganglia and thalamocortical circuits underlie poor inhibitory control and that disruption of one or more of these circuits contributes to poor inhibition and inappropriate filtering of information. The thalamus in particular is a key area involved in sensory modulation because almost all sensory information reaches the thalamus directly and it also plays a strong role in the suppression of some sensations (Breedlove, Rosenzweig, & Watson, 2007). Behavioral problems that children with SMD present, including distractibility, impulsivity, disorganization, and emotional dysregulation, may occur as a result of difficulties with suppressing irrelevant sensory stimuli due to poor thalamic filtering and sensory gating (Davies & Gavin, 2007) rather than difficulties with regulating cortical responses (Barkley, 1997), which would suggest a greater "bottom-up" component to behavioral problems.

Sensory processing may be linked inextricably to executive-function control processes, and all final-acted sensory-based behaviors may be the result of cortical-basal ganglia interactions involving the thalamus, basal ganglia, neocortex, and cerebellum (Koziol et al., 2011). Given that ADHD has been linked to the same structures (Cherkasova & Hechtman, 2009; Ivanov et al., 2010; Kieling, Goncalves, Tannock, &

Castellanos, 2008; Vaidya & Stollstorff, 2008; Valera et al., 2007), understandably the comorbidity between SMD and other disorders such as ADHD is high. This can make teasing out SMD symptoms using behavioral approaches difficult given their shared neuroanatomical and functional underpinnings with other disorders.

Assessment for Diagnosing ADHD

One of the major barriers to diagnosing children with ADHD in schools is the marked heterogeneity in symptom presentation and impairments. ADHD not only is the most common developmental disability in childhood, but also has almost universal comorbidity with one or more other psychiatric disorders (Nijmeijer et al., 2008; Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999). Between 65-89% of all children with ADHD will suffer from one or more psychiatric disorders (Sobanski, 2006), which include both internalizing (13-51%) and externalizing disorders (43-93%), making it difficult for schools to link specific interventions to specific problems.

The *Diagnostic and Statistical Manual of Mental Disorders*, 4^{th} ed., text rev. (*DSM-IV-TR*; American Psychiatric Association, 2000), attempts to address the heterogeneity of ADHD by designating three subtypes: primarily inattentive (ADHD-PI), primarily hyperactive-impulsive (ADHD-PHI), and combined type (ADHD-C). In the past 2 decades, substantial research has examined the *DSM-IV-TR* (2000) subtypes, and multiple studies have brought into question the validity of these distinct groups (Lahey, Pelham, Loney, Lee, & Wilcutt, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), making future taxonomy difficult to develop (Nigg, Tannock, & Rohde, 2010). For example, some researchers have suggested that ADHD-PHI be viewed as a distinct disorder separate from ADHD (Barkley, 2005; Milich et al., 2001) that may be linked to distinct neuropsychological profiles (Nigg, Blaskey, Stawikcki, & Sachek, 2004). A more etiologically informed approach to examining heterogeneity across and within subtypes may improve the diagnostic validity of ADHD (Willcutt & Carlson, 2005), but also better target interventions in school.

As of now, ADHD is conceptualized as a behavioral disorder (DSM-IV-TR, 2000) and multiple studies suggest that practitioners rely predominantly on observations and rating scales for diagnostic purposes (Demaray et al., 2003). The National Association of School Psychologists (2005) recommends that the identification of ADHD include (a) formal observations in multiple settings; (b) interviews with the student and relevant adults; (c) completion of rating scales by family, teachers, and student; (d) review of developmental, school, and medical histories; and (e) formal tests to measure attention, persistence, and related characteristics. Even so, one national survey of school psychologists on assessment practices within the school systems revealed that half of school psychologists refer to medical doctors outside the school system for the assessment and diagnosis because of the variability in state laws and school system-wide approaches (Demaray et al., 2003). Demaray et al. (2003) also found that the most frequent techniques used in diagnosing ADHD are direct observations and rating scales. For school districts that continue to utilize pediatricians for assessment and diagnosis, the American Academy of Pediatrics Committee on Quality Improvement, Subcommittee on Attention-Deficit/Hyperactivity Disorder (2000) recommended that all professionals, including psychologists and pediatricians, use multimethod and multimodal techniques, which include rating scales and individual testing, to assess ADHD comprehensively. Wolraich et al. (2010) sampled 1,603 pediatricians from 1999 to 2005 and found a greater adherence to these guidelines over time; however, there is still a considerable reliance on interviews (81%), and 67% use teacher rating scales (up from 49% in 1999) to make a diagnosis. In general, teacher rating scales are the most commonly used tool in assessing ADHD in schools (Barkley, 2006; Demaray et al., 2003; DuPaul & Stoner, 2003). While they do not reveal the "truth," rating scales do provide reliable perceptions of a given construct (Myers & Winters, 2002). Teacher ratings in particular are important because they summarize extensive and accumulated observations of behaviors that impact the learning of a child in school (Busse & Beaver, 2000). In addition, teacher ratings on ADHD have been shown to be good at differentiating children with ADHD from those without ADHD (Barkley, 2006; DuPaul & Stoner, 2003; Nigg et al., 2004; Power, Costigan, Leff, Eiraldi, & Landau, 2001). Rating scales not only are an inexpensive and time-efficient means of gathering data (Barkley, 2006), but also are norm referenced, which helps determine from a teacher's perspective the extent to which a child's behavior deviates from that of his or her peers. This is particularly important given that teachers continue to demonstrate poor knowledge and clinical judgment regarding behaviors typically associated with ADHD (Amador-Campos, Forns-Santacana, Guárdia-Olmos, & Peró-Cebollero, 2006; Rinn & Nelson 2009; Sciutto, Terjesen, & Bender-Frank, 2000); however, teachers may be getting better at judging the frequency of occurrence of specific behaviors that typically are included on ADHD rating scales (Kypriotaki & Manolitsis, 2010).

As mentioned earlier, cognitively oriented top-down processing views of ADHD have resulted in the development of some rating scales that deviate from *DSM-IV-TR* (2000) criteria. The BADDS (Brown, 2001), in particular, captures many executive-function weaknesses associated with ADHD based on Brown's model of six clusters: activation, attention, effort, emotion, memory, and action. Despite taking a more comprehensive approach toward looking at ADHD as a disorder of executive functions, teacher ratings on the BADDS correlate well with other rating scales that target *DSM-IV-TR* (2000) criteria more narrowly (Brown, 2001).

Despite the many benefits of using ADHD scales, the several weaknesses to their use include source effects (characteristics of the rater), accuracy based on wording and context (Barkley & Murphy, 1998; Burns, Gomez, Walsh, & Moura, 2003; DuPaul, 2003), and bias (Chang & Stanley, 2003; Hosterman et al., 2008). Source effects may stem from cultural differences of raters (Alban-Metcalfe, Cheng-Lai, & Ma, 2002), or be caused by individual biases, such as halo effects (Fiske, 1987). Conversely, source effects may reflect true differences in behavior across settings by different informants (Greenbaum, Dedrick, Prange, & Friedman, 1994). Accuracy problems, on the other hand, may be a function of ambiguity or poor wording of items on ADHD rating scales (Barkley & Murphy, 1998). Newer ADHD scales use almost the exact wording from the DSM-IV TR, which poses two problems according to Burns et al. (2003). First, the items on ADHD scales may not be appropriate to the situation of the rater. Some items are more appropriate for classroom behaviors, while other items better reflect behaviors seen at home. Secondly, the general wording on ADHD scales may fail to discern the correct clinical meaning. Burns et al. (2003) argue that items such as "often does not seem to listen when spoken to directly" may be too general and could reflect different etiologies for different individuals or more than one underling cause. In fact, rating scales contribute to misclassification rates as frequently as 30% of the time (Myers & Winters, 2002), which may be the result of an overreliance on rating scales (AAPCQI, 2000; Demaray et al., 2003), and also failure to employ observations and *direct* measurement of cognitive, neuropsychological, academic, and behavioral functioning to parse out subtypes and comorbidity (Hale et al., 2011). ADHD scales also may fail to reflect contextual issues where reported behaviors may simply reflect environment versus true psychopathology (Myers & Winters, 2002). In addition, many symptoms detected by rating scales represent state conditions versus underlying traits and thus wax and wane in different situations and across the childhood period (Myers & Winters, 2002). Taken together, rating scales may underestimate environmental factors that lead to the observed behaviors, in addition to previously discussed source effects.

One of the best ways to minimize source effects and other types of errors is to design a reliable and valid scale (Burns, et al., 2003; DuPaul, 2003; Myers & Winters, 2002). Myers and Winters (2002) articulated in their 10-year review of the psychometric properties of rating scales that a reliable scale must have the following: consistency of the items comprising the scale, stability of the scale over time and measurements, agreement between different raters using the scale, and concordance between similar forms of a scale. Of greater importance, a good rating scale must have strong validity. Validity refers to whether a scale is measuring what it was designed to measure (Corcoran &

Fischer, 2000; Piacentini, 1993). Establishing validity for diagnostic purposes means that a scale must have strong content, criterion, and construct validity, which can take years to establish. Content validity, for example, requires that items represent the entity being measured (Myers & Winters, 2002) and may be an effective way to reduce source effects (Gomez et al., 2003). Criterion validity is empirically based and is assessed in relation to other scales (AERA et al., 1999). Finally, construct validity, which examines whether a scale taps into a particular theoretical construct (Myers & Winters, 2002), is of greatest importance when trying to assess underlying physiological and psychological processes, such as ADHD and sensory processing.

As Gomez et al. (2003) pointed out, the wording of items on rating scales is important to address better the underlying clinical meaning of a symptom and the context and to reduce source effects. The Connors 3rd Edition (3-T) (Connors, 2008) closely aligns the ADHD Index items with *DSM-IV-TR* (2000) criteria for the teacher form, but some of the items are worded more specifically than the *DSM-IV-TR* (2000) criteria. For example, one of the items addressing inattention that is worded “Fails to complete schoolwork or tasks (even when he/she understands and is trying to cooperate),” might tap into the inattentive construct from a teacher’s perspective better than the *DSM-IV-TR* (2000) wording of “often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand directions).” In addition to subtle wording changes in teacher rating scales, the Connors’ 3-T made changes to items to address frequent comorbid diagnoses and differential diagnoses such as conduct problems, despite being a “narrow band scale." In part, this might help address some of the heterogeneity problems in ADHD by teasing out related and similar problems.

Assessment of Sensory Processing

Currently, sensory processing dysfunction is identified predominantly through observations and self-reports. While physiological approaches are in their infancy stage as a potential avenue for diagnosis, a number of survey instruments are being used to assess atypical sensory processing. The Sensory Profile (Dunn, 1999) was standardized on 1,200 children and is used commonly in assessing sensory-processing difficulties in children. This measure looks at seven areas of processing, including Tactile Sensitivity, Taste/Smell Sensitivity, Movement Sensitivity, Under-responsive/Seeks Sensation, Auditory Filtering, Low Energy/Weak, and Visual/Auditory Sensitivity. A shorter version, called the Short Sensory Profile (SSP; McIntosh, Miller, & Shyu, 1999), is frequently used in studies because of its short administration time (10 min) and value in screening for atypical sensory processing (Dunn, 1999; McIntosh, Miller, & Shyu, 1999). The Infant/Toddler Sensory Profile (Dunn, 2002), Adolescent/Adult Sensory Profile (Brown & Dunn, 2002), Sensory Experiences Questionnaire (Baranek, David, Poe, Stone, & Watson, 2006), Sensory Processing Measure (Parham, Ecker, Kuhaneck, Henry, & Glennon, 2006), and the Sensory Over-responsivity Scale (Schoen, Miller, & Green, 2005) also are used to identify the frequency of behaviors in response to sensory stimuli, including touch, vision, sound, taste, smell, and movement. Each of these scales has been used in classifying children with overresponsivity, underresponsivity, and sensation-seeking problems. The newest scale, which is still being developed, is the Sensory Over- and Under-Responsivity Scale (Schoen, Miller, & Green, 2008).

Though seemingly ubiquitous in psychopathology, few studies have looked at sensory processing purely from an educational standpoint to determine if teachers perceive symptomatology not only as “severe” enough to warrant intervention, but also as distinct from other problematic behaviors in the classroom, such as hyperactivity or impulsivity. Characteristics of SMD include difficulty regulating and organizing behavioral responses to sensory input (Miller et al., 2007), as well as over- or under-responsiveness to one or more sensory modalities (Miller, 2006; Miller et al., 2007). Two instruments are available to address sensory processing in school environments: the Sensory Processing Measure School Form (Parham et al., 2006) and the SPSC (Dunn, 2006).

Assessment of Sensory Responsiveness

Currently, the extent to which environmental factors play a role in sensory processing and/or modulation is unclear, but there may be physiological differences in sensory gating, in pain perception, and even within the autonomic nervous system. At present several approaches to measuring sensory responsiveness are used, including the Prepulse Inhibition (PPI), P50 suppression, Electodermal Responses (EDR), and, most recently, Event-Related Potentials (ERPs). PPI uses paired stimuli and presents a weaker stimulus first and then a stronger stimulus. This causes a motor startle response. The P50 is an evoked response to sensory input identifiable using an electroencephalogram (EEG). EDR uses electodermal responses—changes in skin electrical conductance—to assess either the strength of the responsiveness or the habituation to sensory stimuli. ERPs are typically an average EEG response to some kind of stimulus (Griskova & Arnfred, 2008). These instruments have been used to assess sensory gating, autonomic nervous system differences, and even pain perception. As measured by the P50, Davies and Gavin (2007) found that EEG readings of children exhibiting SPD symptoms had significantly less sensory gating and registration, correlated with atypical sensory nervous system processing given their inherent difficulty with sensory registration. Davies et al. (2009) further found sensory-gating differences as measured by both P50 and N100 ERP in children exhibiting SPD symptoms compared to normal children.

While the test-retest reliability of the P50, N100, and P200 measures are strong for healthy subjects (Rentzsch, Jockers-Scherubl, Boutros, & Gallinat, 2008), the reliability and validity of these measures with children exhibiting SPD symptoms is not well established. There are also moderating effects of age, gender, education, intelligence, and smoking across studies. For example, Davies et al. (2009) looked at the maturation of sensory gating in children with and without SPD symptoms and found that children with SPD symptoms do not improve their gating as a result of biologically driven maturity (physical growth) as normal children do. However, some studies reported no change (at least with some quantitative techniques) based on age (De Wilde, Bour, Dingemans, Koelman, & Linszen, 2007; Lijffjt et al., 2009; Wang, Miyazato, Hokama, Hiramatsu, & Kondo, 2004). Lijffijt et al. (2009) also found that stronger gating may be influenced by more education and greater intelligence. Mixed results as to the impact of gender on gating also have been observed. Some studies indicate that healthy women have weaker gating than men (Hetrick et al., 1996; Patterson et al., 2008; Waldo et al., 1987; White, Kanazawa, & Yee, 2005), whereas Lijffjt et al. (2009) found no gender-based differences. In addition, smoking may increase sensory gating (Kumari & Postma, 2005). In looking at quantitative measures as a means to parse out SMD in children with ADHD, these factors along with other potential confounds will need to be explored further.

Multicultural Considerations

Several multicultural factors are considered in this study. Since the sample of children being utilized will be predominantly African American of low socioeconomic status (SES), there is a risk of drawing inferences based on cultural factors instead of on physiological factors. African American boys have a disproportionately high rate of ADHD, with an estimated prevalence rate of 5.56%, compared to 4.33% for Caucasian boys, and 1.77% for females of all races (Cuffe, Moore, & McKeown, 2005). Miller, Nigg, and Miller (2009) reviewed several peer-reviewed journal articles published between 1990 and 2007 and found that African Americans diagnosed with ADHD also are rated as having more severe cases of the disorder compared to Caucasians. This is not to say that African American children truly have greater severity in symptomatology, but that they are rated as such by teachers and caregivers. Given that the proposed study will include ratings by teachers, sensory processing also may be rated more severely in African American children with ADHD because of the raters' interpretations of sensory behavior. Differences in ratings by this population also may occur as a result of "bias," which Chang and Stanley (2003) conceptualized as variation in teachers' ratings of behavior based on their own ethnicity. Ratings by teachers also might vary as a result of their own personal history and culture (Alban-Metcalfe et al., 2002). For example, Ramirez and Shapiro (2005) found that Hispanic teachers might hold children from their own culture to a higher behavioral standard than they hold Caucasian children. Their study revealed limitations in the use of ADHD rating scales by providing some evidence that perceptions of behaviors based on culture might compromise rating scores.

A second multicultural consideration is the suitability of using a single sensory rating scale with children of various cultures. In several studies, caregivers from various countries and cultures completed a Sensory Profile to determine if this screening tool is a valid measure across cultures. While unclear as to whether observations from caregivers would differ from teacher observations, it is an important starting point. Results have been mixed. Chow (2005) administered the Sensory Profile for Chinese children with typical development and found that Chinese children significantly differed from children in the Untied States by 64.8%, thus questioning the suitability of the use of this scale with Chinese children. These results were inconsistent with a similar study by Satiansukpong (2002), who used the same scale with Thai children from large metropolitan areas and found that internal consistency and internal reliability were adequate. Neuman (2006) found slight differences between Israeli children and children in the United States, but scores were not statistically different. While it may not be pragmatic to validate each rating scale with all cultural and ethnic populations, there is evidence regarding differences across cultures. Regardless of multicultural limitations, determining if teachers perceive sensory-driven symptomatology in the classroom, as well as determining if items on the SPSC can detect symptoms not typically included on ADHD rating scales, will allow future assessments to be more targeted and accurate for all cultures.

Research Hypotheses

It is hypothesized that regardless of whether active or passive strategies are used in managing a high or low neurological threshold, teachers will report that students diagnosed with ADHD frequently exhibit the behaviors associated with SMD on the SPSC. However, results from a rational content analysis of items that compare the SPSC, Connors (3-T), BADDS, ADHD-IV Rating Scales, and *DSM-IV-TR* (2000) diagnostic criteria will reveal significant overlap between ADHD and SMD symptomatology in most domains. Based on these hypotheses, the following results are anticipated:

1. Teacher ratings of children diagnosed with ADHD using the SPSC will produce scores in the Definite Difference range within the Seeking quadrant.
2. Teacher ratings of children diagnosed with ADHD using the SPSC will produce scores in the Definite Difference range within the Registration quadrant.
3. Since Sensitivity and Avoiding quadrants both measure sensory overresponsiveness (SOR), teacher ratings of children diagnosed with ADHD using the SPSC will produce scores in the Definite Difference range on either the Sensitivity or Avoiding quadrant.
4. A rational content analysis of SPSC items that comprise the Seeking, Registration, and Sensitivity quadrants will reveal significant overlap with

items on the Connors 3T, BADDS, and diagnostic criteria from the *DSM-IV-TR* (2000).

5. A rational content analysis of items that comprise the Avoiding quadrant will reveal enough unique items to characterize physiologically based behaviors that are exclusive to sensory processing but also represent a definite concern of teachers for students diagnosed with ADHD.

CHAPTER 3

Method

Data Source

The archived data set used in this study includes teacher ratings of 24 children with ADHD that had been collected using the Sensory Profile School Companion (SPSC) form. Each of the students described in the data set attended one of four elementary schools in Prince George's County Public Schools. The students reside in a community that is predominantly African American (90%), with the majority of parents with a high-school education. Roughly 70% of the school population qualifies for free or reduced lunch. All of the students were previously diagnosed with ADHD-C or ADHD-PHI by a medical doctor and, in some cases, a school psychologist as well. None of the students had a comorbid diagnosis that would have warranted other services by the school.

Research Design

For this study, data were analyzed from the SPSC to explore teachers' perception of sensory-processing symptoms in children diagnosed with ADHD and to examine whether the SPSC can differentiate sensory-related behaviors that may be indicative of ADHD from other behaviors typically associated with ADHD. The primary goal of this study was to determine if teachers perceive behaviors indicative of sensory-processing difficulties in children with ADHD. Descriptive statistics were calculated for the raw scores associated with sensory-processing areas. Raw scores were generated for the sample, and sensory profile types were assigned to each student based on teacher ratings. Frequency counts of the number of students in each score category within each sensory profile type were generated. The percentage of children showing typical, probable, or definite differences in the areas of Seeking, Avoidance, Registration, and Sensitivity were reviewed to establish patterns of sensory processing. Secondly, a rational content analysis was conducted comparing all items on the SPSC with the items on the Conners-3T, the BADDS, and the ADHD-IV Rating Scale School Version to determine the number of SPSC items that overlap with ADHD rating scales and the number of SPSC items that describe sensory processing symptoms unique to the SPSC rating scales. Scores from each of the four sensory profile areas were used to generate sensory quadrant scores for each student. An analysis of students' scores in each sensory quadrant was performed to determine if there are enough physiologically based items in the quadrant to differentiate behaviors involving sensory processing that typically are not included on ADHD rating scales from behaviors involving cognitive processing that typically are included on ADHD rating scales.

Measures

The SPSC is a 62-item standardized assessment tool for measuring a student's sensory- processing abilities and their effect on classroom performance in children aged 3-0 years to 11 years-11 months (Dunn, 2006). The SPSC form is designed specifically to identify sensory-related behaviors that are observable by teachers in the classroom. The Teacher Questionnaire yields four quadrant scores (Registration, Seeking, Sensitivity, and Avoiding) based on Dunn's model of sensory processing. The standardization sample included ratings for 585 typically developing children by 62 teachers, as well as a clinical population of 127 students with ADHD, Asperger's disorder, and autism by 61 teachers across the United States.

Reliability was estimated by calculating internal consistency (coefficient alpha) and test-retest reliability. The alpha coefficients for each quadrant of 585 nondisabled students ranged from .89 to .92, indicating a high degree of internal consistency. The test-retest reliability of a sample of 126 students also resulted in strong coefficients that ranged from .84 to .92, suggesting a good stability of scores across each domain. Content validity was established during the development of the SPSC through interviews and pilot studies using the Sensory Profile Caregiver Questionnaire. Correlations between the SPSC and Sensory Profile Caregiver Questionnaire are mixed. There are significant relationships between parent and teacher reports on Avoiding, Sensitivity, and Registration quadrants, with scores ranging from .53 to .84; however, there is no significant relationship between Seeking quadrant scores at home and school. The SPSC can be administered in approximately 15 minutes. Table 1 provides examples of items from each sensory-processing pattern of the SPSC.

Domain	Example item
Seeking	Item 4: Hums, whistles, sings, or makes other noises throughout the day Item 15: Adds more detail to drawing and coloring than other students
Avoiding	Item 21: Avoids eye contact Item 32: Withdraws from activities
Registration	Item 23: Slouches, slumps, or sprawls in chair Item 50: Shows little emotion regardless of the situation
Sensitivity	Item 52: Is bothered by rules being broken Item 53: Is bossy with classmates or peers

Figure 2. Example Items from the Sensory Profile School Companion

The Connors' 3-T is a 115-item questionnaire completed by teachers on a written form or online using a password to assess a variety of behaviors associated with ADHD and associated symptoms for children ages 6-18 years. The Connors' 3-T was standardized on a large stratified normative sample of 1,200 children. The Connors' 3-T yields strong reliability, with an internal consistency between .77 and .95, test-retest scores between .83 and .87, and an interrater reliability of .55 to .77. The Connors' 3-T is also considered a valid measure in identifying symptoms of ADHD. The scale is supported both empirically and theoretically with consensus in ratings across informants regarding symptomatology. Scores derived from the Connors' 3-T also correlate well with other instruments, and the scale discriminates between relevant groups fairly well.

The BADDS consists of a 44-item questionnaire for children between the ages of 3-7 years and a separate 50-item questionnaire for children between the ages of 8-12 years. Items are grouped into six clusters: organizing, prioritizing, and activating to work; focusing, sustaining, and shifting attention to tasks; regulating alertness, sustaining effort, and processing speed; managing frustration and modulating emotions; utilizing working memory and accessing recall; and monitoring and self-regulating action. The BADDS also is supported empirically with evidence of strong reliability and validity. Internal consistency ranges from .80-.93 on the teacher form for ages 3-7 years, and .76-.94 for ages 8-12 years. Corrected test-retest reliability for cluster scores from teacher ratings range from .78-.89 for children ages 3-7 years, and .84-.91 for ages 8-12 years. The BADDS also is considered a valid scale based on moderate-to-high intercorrelations by teacher ratings. Intercorrelations of cluster scores between teachers ranged from .64-.89 for children ages 3-7 years and .72-.90 for ages 8-12 years. Teacher ratings on the BADDS also can differentiate children with ADHD from children without ADHD and correlate well with other rating scales that measure ADHD symptomatology (Brown, 2001).

The ADHD-IV Rating Scale School Version is an 18-item questionnaire completed by teachers that assesses the core symptoms of ADHD for children ages 4-20 years. The ADHD-IV was standardized on a sample of 2,000 children with an equal number of male and female children from various regions of the United States. The

ADHD-IV yields a strong test-retest reliability of .90, internal consistency of .94, and an interrater reliability of .41. The ADHD-IV also is considered a valid measure in identifying symptoms of ADHD. The scale is supported empirically with items written to reflect *DSM-IV-TR* (2000) criteria for ADHD as closely as possible.

Procedures Used in Creating the Archived Data Set

The school psychologist and student instructional team previously screened and collected data on 24 subjects for classroom interventions. Ten different full-time classroom teachers of third-, fourth-, and fifth-grade students were asked to complete the SPSC for those students having a diagnosis of ADHD and provided an Individual Education Program (IEP) or a 504 plan under the umbrella of Other Health Impairment (OHI). Students with a comorbid educational diagnosis that included an intellectual disability, learning disability, autistic spectrum disorder, emotional disability, deaf-blindness, orthopedic impairment, developmental delay, traumatic head injury, visual impairment, or speech and language impairment were excluded from the data set. Given that the data were archived with no specific identifiers, there is no way of determining if any subject received a later comorbid diagnosis or was identified incorrectly.

The SPSC ratings provided by teachers for each student were reviewed and tallied on a master spreadsheet for analysis. Teacher responses to each of the 62 items were based on a 5-point Likert scale format using the descriptors of “Almost Always” (5); “Frequently” (4); “Occasionally” (3); “Seldom” (2); and “Almost Never” (1). Raw score totals were tallied for each of the four quadrants (Registration, Sensitivity, Seeking, and Avoiding) based on the sum of the items representing the quadrant to determine the sensory-processing patterns. Raw scores also were converted into descriptive category labels. Specifically, quadrant total raw scores that fell within one standard deviation of the standardization sample mean score were assigned the descriptive category of “Typical Performance.” Quadrant total raw scores that were greater than one standard deviation but less than two standard deviations from the standardization sample mean score were assigned the descriptive category of “Probable Difference.” Finally, quadrant total raw scores that were greater than two standard deviations from the mean of the standardization sample were assigned the descriptive category of “Definite Difference.”

Once the item raw scores, quadrant raw score sums, and norm-referenced descriptive categories were entered into a data file, descriptive statistics were generated to examine the SPSC quadrant raw scores and descriptive categories and the quadrant score profiles of the ADHD sample. Additionally, the items of the SPSC were compared with items of the Connors’ 3-T, BADDS, and ADHD-IV Rating Scale School Version to conduct a content analysis to identify physiologically oriented “bottom-up” items that are exclusive to the SPSC and do not overlap with the items on ADHD rating scales.

CHAPTER 4

Results

Sensory Processing

Figure 3 displays the percentage of students with ADHD in the sample assigned to the Definite, Probable, or Typical categories for each sensory-processing subtype.

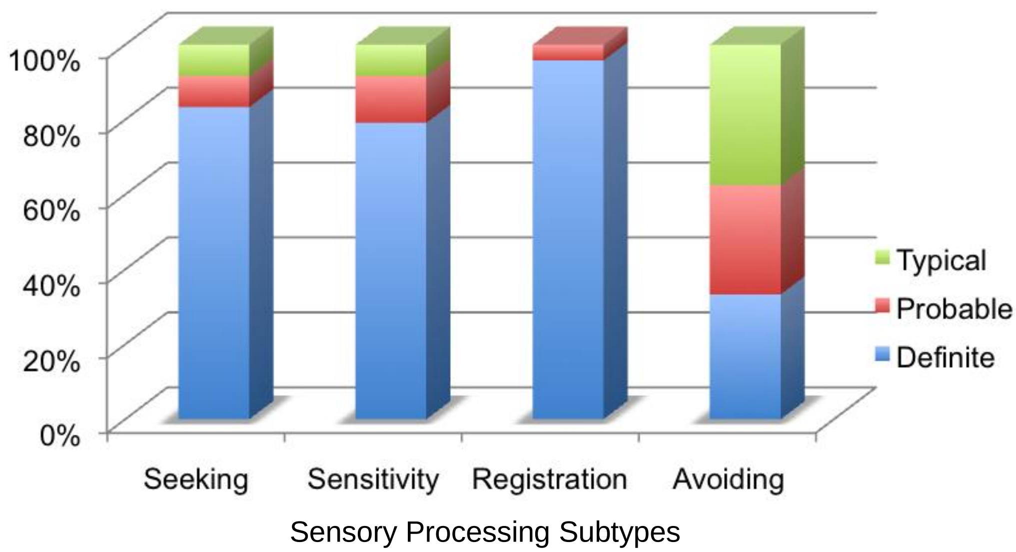

Figure 3. Percentage of studied participants classified as Definite, Probable, or Typical for each sensory-processing subtype. $N = 24$.

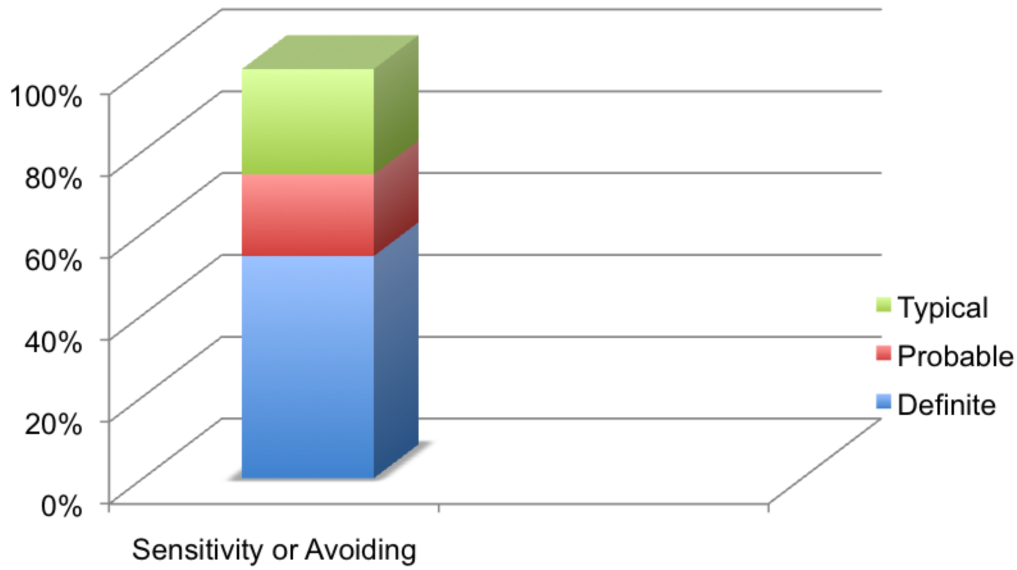

*Figure 4***.** Percentage of students classified as Definite, Probable, or Typical in either the Sensitivity or Avoiding quadrants.

As hypothesized, the majority of teacher ratings of children diagnosed with ADHD using the SPSC produced scores in the Definite Difference range within the Seeking, Registration, and Sensitivity quadrant; however, the majority of children were not rated as having a score in the Definite Difference range on the Avoiding quadrant, though the majority of children were rated as having at least a Probable Difference on this quadrant. Specifically, on the Seeking quadrant, 83% of the students were rated as having a Definite Difference, 8% were rated as having a Probable Difference, and 8% were rated as having No Difference. On the Registration quadrant, 95.8% of the children were rated as having a Definite Difference, 4% were rated as having a Probable Difference, and no students were rated as having Typical performance. The Sensitivity quadrant consisted of 79% of students as having a Definite Difference, 12.5% as having a

Probable Difference, and 8% as having Typical Performance. Scores on the Avoiding quadrant varied much more than those in the other quadrants; teachers perceived only 33% of the students as having a Definite Difference, 29% as having a Probable Difference, and 37.5% as Typical.

Based on the proposed model of SMD, which combines the Sensitivity and Avoiding quadrants to comprise sensory overresponsivity (SOR), 79% of children were rated as having a Definite Difference in either Sensitivity or Avoiding, 29% were rated as having a Probable Difference in either Sensitivity or Avoiding, and 8% of children were rated as Typical for both Sensitivity and Avoiding (see Figure 4).

Rational Item Analysis

Each item on the SPSC was compared with items on the Connors' 3-T, BADDS, ADHD-IV Rating Scales, or *DSM-IV-TR* (2000) diagnostic criteria to determine which items were unique from ADHD symptomatology across these rating scales and the amount of overlap between items on the Seeking, Registration, Avoiding, and Sensitivity quadrants. Overlapping items consisted of items that have similar wording or describe similar-looking behaviors that likely would be perceived in the same way by classroom teachers. Further, items on the Connors' 3-T that reflect associated disorders (e.g., conduct disorder) were excluded.

Sensory Profile School Companion	***DSM-IV-TR***	**ADHD-IV Rating Scale School Version**	**Connors'-3T**	**BADDS**
Misses oral directions in class more than other students	Often does not seem to listen when spoken to directly	Does not seem to listen when spoken to directly	Does not seem to listen to what is being said to him/her	When trying to listen, seems to lose focus and misses out on significant aspects of information
Seems oblivious within an active environment (i.e. seems unaware of activity)		Has difficulty sustaining attention in tasks or play activities		Seems especially sluggish in the morning; appears not to be fully awake or alert until later in the day Tends to be slow to react or to get started; takes a long time to answer questions or to get ready to change activities
Appears to not hear what you say (e.g. does not tune into what you say, appears to ignore you)	Often does not seem to listen when spoken to directly	Does not seem to listen when spoken to directly	Does not seem to listen to what is being said to him/her	Appears not to be listening: needs reminders to pay attention
Slouches, slumps or sprawls in chair				Appears to feel sleepy or tired during class.
Misses written or demonstrated directions more than other students	Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities.	Fails to give close attention to details or makes careless mistakes in schoolwork	Doesn't pay attention to details; makes careless mistakes	
Runs or bumps into things (e.g.. walls, doors, equipment, and other people)		Is "on the go" or acts as if "driven by a motor"	Is constantly moving Acts as if driven by a motor	
Rests head on hands on desk or table during class time or seatwork				Needs reminders to get started or keep working on assignments

Has trouble keeping materials and supplies organized for use during the day	Often has trouble organizing activities	Loses things necessary for tasks or activities Is forgetful in daily activities	Has difficulty organizing tasks or activities Is forgetful in daily activities	
Is clumsy and awkward in movements (e.g. runs into desks and furniture when moving about)				
Is inefficient in doing things (wastes time, moves slowly, makes tasks more complicated.		Has difficulty organizing tasks or activities	Has difficulty organizing tasks or activities	Is inefficient in doing things Seems to have difficulty in getting started on assigned tasks
Leaves items blank on a busy worksheet even when he or she knows the answer				Effort fades quickly; starts assignments, but then “runs out of steam” and doesn’t follow through. Seems to have difficulty in getting started on assigned tasks
Does not steady objects when working (e.g. does not hold paper down when writing)				
Doesn’t watch during instruction, but follows through with instruction				
Comes too close into other people’s personal space when talking				
Shows little emotion regardless of situation				Stares off into space; appears “out of it”
Appears inactive (i.e., seems to lack energy)				Appears to feel sleepy or tired during class

Doesn’t seem to notice when face and hands remain soiled				

Figure 5. Rational content analysis of overlapping items in the Registration quadrant

Figure 5 reveals that 12 items on the Registration quadrant overlap with items on the Connors’ 3-T, BADDS, or ADHD-IV Rating Scale School Form with specific overlap with inattentive symptoms. Only five items on this quadrant describe symptoms that are unique from items on other rating scales that are commonly used to diagnose ADHD. Some of the Registration items overlap with more than one item that describes ADHD symptoms.

Sensory Profile School Companion	***DSM-IV-TR***	**ADHD-IV Rating Scale-School Version**	**Connors' 3T**	**BADDS**
Hums, whistles, sings, or makes other noises throughout the day.	Often has difficulty playing or engaging in leisure activities quietly	Has difficulty playing or engaging in leisure activities quietly	Is noisy or loud when playing or using free time	
Adds more details to drawings and coloring than other students				Tends to erase, scratch out, or start over excessively when writing or drawing
Watches other students when they move around	Is often easily distracted by extraneous stimuli	Is easily distracted	Is easily distracted by sights or sounds	Is easily distracted from tasks by background noises or activities; needs to check out whatever else is going on.
Seeks all kinds of movement, which interferes with daily routines (e.g., can't sit still, fidgets).	Often fidgets with hands or feet or squirms in seat	Fidgets with hands or feet or squirms in seat	Fidgets or squirms in seat	
Is "on the go"	Is often "on the go" or often acts as if driven by a motor	Is "on the goal" or acts as if driven by a motor	Acts as if driven by a motor Is constantly moving	Seems constantly to be moving around, talking or making noise; can't be still for long
Fidgets during activities (e.g., moves around, taps desk)	Often fidgets with hands or feet or squirms in seat		Fidgeting Is constantly moving	Seems constantly to be moving around, talking or making noise; can't be still for long
Gets up and moves around more than other students	Often gets up from seat when remaining in seat is expected	Leaves seat in classroom or in other situations in which remaining seated is expected	Leaves seat when he/she should stay seated. Is constantly moving	Seems constantly to be moving around, talking or making noise; can't be still for long
Seems to find excessive reasons for approaching the teacher				
Touches people and objects to the point of irritating them				

Plays or fiddles with objects or school supplies (e.g., pencils, notebooks, folders)	Often fidgets with hands or feet or squirms in seat	Fidgets with hands or feet or squirms in seat.		
Displays unusual need to touch certain toys, surfaces, or textures (i.e., constantly touching objects)				
Seems more curious than other students				

Figure 6. Rational content analysis of overlapping items in the Seeking quadrant

Figure 6 reveals that eight items on the Seeking quadrant overlap with items on the Connors' 3-T, BADDS, ADHD-IV School Form, or *DSM-IV-TR* (2000) criteria with specific overlap with hyperactive symptoms. Only four items on this quadrant describe symptoms that are unique from items commonly included on ADHD scales. Some of the Seeking items overlap with more than one item that describe ADHD symptoms.

Sensory Profile School Companion	***DSM-IV-TR***	**ADHD-IV Rating Scale School Version**	**Connors' 3-T**	**BADDS**
Is distracted or has trouble functioning if there is a lot of noise in the area	Is often easily distracted by extraneous stimuli	Is easily distracted	Inattentive, easily distracted Has trouble concentrating	Is easily sidetracked: starts one task and then switches to a less important task
Tells others to be quiet	Often interrupts or intrudes on others (e.g. butts into conversations or games)	Interrupts or intrudes on others	Interrupts others (e.g., butts into conversations or games)	Appears to get irritated easily or short-fused with sudden outbursts of temper Seems easily irritated or impatient in response to apparently minor frustrations Interrupts or intrudes on others
Has difficulty participating in group activities if there is a lot of talking.	Often does not seem to listen when spoken to directly	Does not seem to listen when spoken to directly	Does not seem to listen to what is being said to him/her	Appears not to be listening: needs reminders to pay attention Seems to have difficulty in speaking out or standing up for himself/herself
Becomes distressed during assemblies, lunch, or other large gatherings				
Is overly bothered by loud or unexpected noises (e.g., fire alarm, books slamming to the floor, doors slamming, announcements, bells)				

Has difficulty participating in group activities where there is a lot of talking	Is often easily distracted by extraneous stimuli	Is easily distracted Has difficulty waiting turn	Is easily distracted by sights or sounds	Is easily sidetracked: starts one task and then switches to a less important task Is easily distracted from tasks by background noises or activities; needs to check out whatever else is going on
Notices even small changes in the room or desk organization				
Comments on small details in objects or pictures that others haven't noticed				
Looks away from tasks to notice all other activity in the room	Is easily distracted by extraneous stimuli	Is easily distracted	Is easily distracted by sights or sounds	
Startles at unexpected movements near desk or around room (e.g., another student getting up quickly, objects falling off desk)				
Is fidgety or disruptive when standing in line or close to other people (e.g., getting on the bus, sitting in an assembly)	Often has difficulty awaiting turn	Has difficulty awaiting turn	Has difficulty waiting for his/her turn.	Effort fades quickly; starts assignments, but then "runs out of steam" and doesn't follow through. Seems constantly to be moving around, talking or making noise; can't be still for long
Wants to wipe hands quickly or often during messy tasks				

Is easily upset by minor injuries (e.g., bumps, scrapes, cuts)			Gets overstimulated or “wound up”	
Uses only fingertips to work on projects that require manipulation				
Is bothered by rules being broken				
Is bossy with classmates or peers				Seems easily irritated or impatient in response to apparently minor frustrations Interrupts or intrudes on others
Can be described as over-reactive or dramatic when compared to classmates or peers			Gets over-stimulated or “wound up”	Appears to get irritated easily or short-fused with sudden outbursts of temper.

Figure 7. Rational content analysis of overlapping items in the Sensitivity quadrant

Figure 7 reveals that nine items on the Sensitivity quadrant overlap with items on the Connors’ 3-T, BADDS, ADHD-IV Rating Scale School Form, or *DSM-IV-TR* (2000) criteria. Eight items on this quadrant describe symptoms that are unique from items commonly used to diagnose ADHD in schools. Some of the Sensitivity items overlap with more than one item and frequently describe impulsive, inattentive behaviors associated with ADHD. Items also reflect difficulty managing frustration and modulating emotions found on the BADDS.

Sensory Profile School Companion	***DSM-IV-TR***	**ADHD-IV Rating Scale School Version**	**Connors-3T**	**BADDS**
Holds hands over ears to protect them from sound				
Avoids eye contact				
Stands or sits at the side of the playground during recess				
Withdraws from activities				
Is slow to participate in physically active tasks or activities				
Intentionally withdraws from active environments or situations (e.g., retreats to a quiet area in the classroom)				
Refuses to participate in team games (e.g., soccer or basketball)				
Flinches when you get in close proximity or touch his or her body				
Refuses to participate in activities that are messy (e.g., art projects, using glue or paint)				
Doesn't express emotions (i.e., has a flat unresponsive affect)				
Doesn't have a sense of humor				
Can be described as inflexible when compared to classmates or peers				
Has difficulty tolerating changes in routines, plans, and expectations				Appears to get irritated easily; "short-fused" with sudden outbursts of temper

Is stubborn or uncooperative				
Perseverates to the point that he or she cannot move on (i.e., can’t shift gears).				Is excessively rigid or perfectionistic; tends to waste time on insignificant details of work or has to start over repeatedly if a paper is not perfect
Withdraws when there are changes in the environment or routine				
Is frustrated easily				Seems easily irritated or impatient in response to apparently minor frustrations Appears to get irritated easily; “short-fused” with sudden outbursts of temper

Figure 8. Rational content analysis of overlapping items in the Avoiding quadrant

Figure 8 reveals that only three items on the Avoiding quadrant overlap with items on the Connors’ 3T, BADDS, ADHD-IV Rating Scale School Form, or *DSM-IV-TR* (2000) criteria. Fourteen items on this quadrant describe symptoms that are unique from items commonly used to diagnose ADHD in schools. All overlapping items reflect difficulty managing frustration and modulating emotions found on the BADDS.

CHAPTER 5

Discussion

The purpose of this study was to utilize archival data, collected using the Sensory Profile School Companion (SPSC), to examine if children previously diagnosed with ADHD are perceived by teachers to have SMD. Given the overlap in presentation of ADHD and SMD symptomatology, it may be difficult for classroom teachers to discern the subtle differences bbehaviorally, and thus a rational item analysis was conducted to determine if items on the SPSC differentiate unique sensory-based behaviors from ADHD symptomatology found on various rating scales used in school to assist in the diagnosis of ADHD. Based on Dunn's model of sensory processing, which reflects SMD, the following quadrants were examined.

Sensory Seeking/Craving (SS)

Based on Dunn's model, children with SS have high sensory thresholds and actively seek out means to meet that threshold. It was hypothesized that children previously diagnosed with ADHD would be perceived by teachers as having a "Definite Difference" (at or above two standard deviations from the norm reference group) in SS behaviors. Out of the 24 students in this pilot study, 88% of students with ADHD were perceived as having a Definite Difference in SS behaviors. These results are consistent with the findings from James et al. (2011), who noted that 75% of the ADHD sample from their study had significant SS behaviors based on parent responses using the Short Sensory Profile (SSP). However, these results differ from Dunn's clinical study (2006), which used the SPSC to compare teacher ratings of 59 students with ADHD with matched nondisabled peers and found no significant differences between ADHD and normal groups, $F = 3.19$, $p < .077$. Results from the item analysis reveal significant overlap of item content between seeking items and items on the C-3, BADDS, ADHD Rating Scale-IV: School Version, and DSM-IV criteria. Items on the Seeking quadrant predominantly overlap with symptoms of hyperactivity and few items reflect unique behaviors apart from ADHD symptomatology. These findings corroborate the findings of James et al. (2011) who reported that items on the parent form of the SSP (parent version) also overlap with hyperactive symptoms. Since there are few items on the Seeking quadrant that are unique from hyperactive items, not surprisingly children with ADHD-C frequently are rated as having a Definite Difference on this scale.

Theoretically, the symptoms of hyperactivity in children with seeking/craving behaviors may be reduced when provided the appropriate sensory-based intervention (James et al., 2011), but research does not support this view as of yet. As an important step, the differentiation between seeking behaviors and hyperactivity needs to be established to determine if children with seeking/craving behaviors benefit from more targeted sensory-based interventions. As of now, there are not enough unique items on the SPSC for teachers to discern seeking/craving behaviors from typical hyperactivity associated with ADHD.

Avoiding and Sensitivity/SOR

Based on Dunn's model, children with SOR have low neurological thresholds, but depending on their self-regulation strategies, they may have an Avoiding pattern (actively withdrawal in dealing with sensory input) or Sensitivity pattern (passively dealing with input) to meet their threshold. Children with ADHD were rated more frequently as having a Definite Difference in Sensitivity (79%) as opposed to Avoiding (33%). This discrepancy can be attributed to better wording on the Avoiding quadrant or to the fact that children with ADHD are more likely to employ strategies more characteristic of a Sensitivity pattern than an Avoiding approach (e.g., telling others to be quiet versus running away from distressing sounds). In trying to differentiate aspects of SMD from ADHD, frequently many researchers lump Avoiding and Sensitivity into one subtype, but there are far more items on the Avoiding quadrant that can be differentiated from items on ADHD rating scales and may therefore better differentiate SMD from ADHD in the classroom.

To date, SOR is also the only SMD subtype that has evidence of being a unique entity. Reynolds and Lane (2008) presented three case studies of children with SOR without a comorbid condition, and more recently Carter et al. (2011) conducted a large-scale study in which more than 74% of subjects displayed SOR and did not meet criteria for any *DSM-IV-TR* (2000) diagnosis. However, as with this current study, the symptoms of SOR were assessed using a rating scale, which lends itself to the inherent weaknesses that rating scales have in making inferences of underlying physiological processes based on observations. Though beyond the scope of this study, prior research suggests that SOR may overlap with anxiety. Disentangling the SOR from anxiety from a behavioral perspective may be challenging in the same manner as discerning SS behaviors from hyperactivity is challenging. While SOR and anxiety can occur together or independently (Lane, Reynolds, & Thacker, 2010), future studies will need to evaluate further the discriminative validity of items on the SPSC with rating scales that target behaviors likely to be indicative of anxiety.

Registration/SUR

Similarly to seekers, children with a Registration pattern also have high neurological thresholds but have a more passive self-regulation style and often disregard or are not fully cognizant of sensory cues. Based on the item analysis, there was considerable overlap between items on the Registration quadrant and items on the ADHD rating scales with specific overlap in items that describe inattention. Currently, little research validates this construct as occurring independently from SS and SOR, and while the construct has face validity, this quadrant will be better supported with more unique items that address high neurological thresholds, such as “Does not steady objects when working (e.g., does not hold paper down when writing),“ versus items that appear to measure more ambiguous behaviors associated with ADHD, such as “Has trouble keeping materials and supplies organized for use during the day.” This will help increase discriminative validity by improving sensitivity and specificity. As of now, both Seeking and Registration items collectively comprise most of the DSM-IV criteria for ADHD-C and lack an acceptable neurobiological foundation.

General Discussion

Although ADHD is being viewed increasingly as a heterogeneous neurodevelopmental disorder that should be diagnosed using multimethod and multimodal approaches, there is still a heavy overreliance on teacher rating scales for making diagnoses and for gathering information about students (Wolraich et al., 2010).

Given their behavioral nature, rating scales can have difficulty capturing underlying physiological processes, such as those theoretically associated with the components of SMD. In this regard, the wording of items on these scales is important for establishing discriminative validity and ultimately, for establishing construct validity. Similar to those in prior studies, children with ADHD in this sample were rated commonly as having Definite Differences across SMD areas; however, most items that reflect Seeking/Craving, Registration, and Sensitivity appear too similar to items on commonly used ADHD rating scales for psychologists and occupational therapists to differentiate behaviorally SS and SUR from ADHD.

The overlap between items from the Seeking, Registration, and Sensitivity quadrants and ADHD symptomatology may be conceptualized in various ways. First, Seeking/SS behaviors may be a subset of hyperactivity, much like a maple tree is a subset of the general concept of tree. Both have the same structural characteristics, but one is more specific and descriptive than the other. An observable seeking pattern of behavior may occur as a result of the same cortical and subcortical structures identified in ADHD research, but there may be specific patterns or pathways by which these structures interact, resulting in the same or similar observable behaviors as described by commonly used rating scales.

A second explanation as to the overlap in items between Seeking and Registration with ADHD symptomatology may be a function of two distinct disorders or etiologies with the same behavioral manifestations. Much like a bacterial infection can cause the same symptoms as a viral infection, distinguishing the underlying causes based on observation is difficult. Further, one can conceivably have both a viral and a bacterial infection. Currently, there is a great need for research to validate the unique etiological qualities of SS and SUR, especially with quantitative measuring techniques. As of now, ADHD and SMD, like most developmental disorders, are not diagnosed from biological markers (James et al., 2011). Identification of the underpinnings of these disorders is sorely needed to better distinguish these disorders.

Finally, the overlap in items simply may be the result of two different fields providing their own nomenclature for the same underlying problems. In one study, Ben-Sasson et al. (2007) found that the same behaviors can be interpreted differently by psychologists and occupational therapists based on differences in training and theoretical perspectives. Collaboration between these fields in terms of training and research is also sorely needed to avoid problems in nomenclature and public confusion.

Contrary to Seeking/SS, Registration/SUR, and Sensitivity items, the majority of items that measure Avoiding behaviors are unique and although may still be characteristic of ADHD, can differentiate new behaviors apart from typical ADHD symptomatology seen on teacher rating scales. While the current study yielded several students with probable differences in SOR, it is important to note that the population of children with ADHD studied in this sample come from low socioeconomic backgrounds and are at greater risk for prenatal risks associated with alcohol, stimulants, and stress (Tucker & Dixon, 2009). Several studies have linked these risk factors with both ADHD (Kieling et al., 2008; Biederman, Faraone, & Monuteaux, 2002) and SOR (Schneider et al., 2008; Atchison, 2007; Crepeau-Hobson, 2009). Though beyond the scope of this study, the driving factors that led to symptoms of both SMD and/or ADHD symptomatology for this population may be a function of prenatal, perinatal, and environmental factors. As such this study may highlight an ADHD phenotype that may result from these risk factors.

As with ADHD, studies of sensory processing highlight the need for multimethod and multimodal approaches when assessing or making a diagnosis. The use of teacher rating scales alone is inadequate for an accurate diagnosis; however, disorders that warrant services in schools must manifest in the classroom and there must be an impact on academic performance. As such, items that assess SMD must address different symptoms from other disorders to avoid diagnostic redundancy, and their adverse effects must be observable in the classroom. Since children with ADHD and SMD display a wide array of behaviors, comprehensive neuropsychological testing is needed to better identify the symptoms that drive maladaptive behaviors associated with ADHD and SMD.

Implications of the Findings

SMD or components of SMD may have unique biological markers that distinguish them from other disorders, but these predominantly bottom-up features are difficult to distinguish using the items on the SPSC. While children with ADHD may present with SMD symptoms in school, these results underscore the need for narrow-band rating scales that target physiological concerns in order to maximize sensitivity and specificity. In order to best target interventions in school for sensory-related problems, items on rating scales need to reflect the targeted construct accurately, which will result in studies that can determine more accurately if sensory-related interventions work in school.

Limitations of the Study

There are inherent limitations in making inferences regarding involvement of underlying sensory-related processes based on judgments of overt behaviors using rating scales. With no quantitative measurement techniques being utilized for sensory gating, only perceptions of observable behaviors can be utilized. Further, quantitative sensory techniques (QST) are still considered poorly anchored for gauging sensory processing in children. There have been recent efforts to improve the standardization and determine proper thresholds for these instruments (Kelly, Cook, & Backonja, 2005; Rolke, Baron, & Maier, 2006), but standards for testing, normative data, and consensus on guidelines for interpretation of data from QST in the most general sense are lacking, making validating judgments using rating scales with objectively measured physiological data difficult (Backonja et al., 2009). In a recent review and analysis of QST, Backonja et al. (2009) concluded the following:

> For QST to be widely accepted and implemented in routine clinical practice there are many areas that still need to be better developed and standardized. Those areas include: determination about the influence of psychological factors specific to individual patients that may affect participation in QST; establishment of screening tools and mechanisms to exclude patients who are unlikely to be able to participate in QST; standardization of QST instructions; establishment of normative data and test-retest variability, on the basis of which interpretation of

> results will be possible; establishment of specificity and sensitivity for common neurologic and pain-threshold related disorders, which should assist in reaching specific diagnoses; and training of the examiners. As these issues are being resolved QST will continue to solidify its place in the evaluation of the somatosensory nervous system. (645)

Given that the data in this study are archived, information regarding the characteristics of teachers (years of teaching experience, age, SES, gender, and ethnicity) is limited, which may contribute to source bias (Chang & Stanley, 2003), as well as the characteristics of the students (ethnicity, gender, and whether the students received a subsequent diagnosis). Further, class sizes vary slightly by classroom, and some teachers may have longer and more intimate contact with students than may others. Given this unique population in terms of SES and ethnicity, there may be cultural or economic factors contributing both to behaviors exhibited and to teacher perceptions of exhibited behaviors. For example, some studies suggest that African Americans experience higher levels of anxiety (Neal & Turner, 1991), which could elevate scores on the Avoiding scale, whether observed behaviors are confused with anxiety (Ben-Sasson et al., 2007) or if students experience both (Lane, Reynolds, & Thacker, 2010). Scores also may be elevated based on the ethnicity of the raters (Chang & Stanley, 2003) or based on the ethnicity of the student (Miller et al., 2009). Miller et al. (2009) found that African Americans with ADHD frequently are rated more severely on rating scales than Caucasians. Given the overlap between behaviors associated with ADHD and SMD, African American children in this study also may be rated more severely than Caucasian children, especially given their vulnerability and higher risk of teratogenic agents.

Future Direction for Research

Despite the high prevalence of ADHD and SMD, few studies have been conducted by psychologists that differentiate these disorders clinically and/or in the classroom. This study will need to be replicated using a larger, diverse sample of children that mirrors the U.S. population to determine if children with ADHD are perceived by teachers as having sensory-processing dysfunction with particular emphasis on Avoiding symptoms, which consist of items that are most different from items based on ADHD criteria. Furthermore, items on the SPSC and other rating scales that measure sensory processing will need to be compared with items on other types of narrow-band rating scales (e.g., measures of anxiety), as well as on broad-based scales that measure various internalizing and externalizing disorders to ensure discriminative and convergent validity.

Given that children with sensory-processing dysfunction are theorized to have abnormal gating, there is a great need for researchers to study current quantitative measuring techniques and properly validate them with the normal population. Once sensory processing is properly anchored, determining the relationship between ADHD and sensory-processing dysfunction will be easier.

As Gomez et al. (2003) pointed out, the wording of items on rating scales is important to address better the underlying clinical meaning of a symptom and the context and to reduce source effects. In recent years, some rating scales, such as the Connors' 3T have created better items that are less ambiguous. Items such as "Fails to complete schoolwork or tasks (even when he/she understands and is trying to cooperate),” might tap into the inattentive construct from a teacher’s perspective better than the *DSM-IV-TR* (2000) wording of “often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand directions).” The SPSC will achieve better discriminative validity by including more items that are more “bottom-up” oriented to reflect sensory gating as opposed to items that are worded too similarly to items on commonly used rating scales used to diagnose ADHD. Taking a more etiological approach in constructing items will make the study of sensory processing as a whole easier and will better operationally define the terms. Furthermore, progress in this area could be enhanced through collaboration of both occupational therapists and psychologists.

References

Ahn, R. R., Miller, L. J., Milberger, S., & McIntosh, D. N. (2004). Prevalence of parents perceptions of sensory processing disorders among kindergarten children. *American Journal of Occupational Therapy*, *58,* 287-293.

Alban-Metcalfe, J., Cheng-Lai, A., & Ma T. (2002). Teacher and student teacher ratings of attention-deficit/hyperactivity disorder in three cultural settings. *International Journal of Disability, Development and Education, 49*(3), 281-299.

Amador-Campos, J.A., Forns-Santacana, J., Guárdia-Olmos, & M. Peró-Cebollero. (2006). DSM-IV Attention deficit hyperactivity disorder symptoms: Agreement between informants in prevalence and factor structure at different ages. *Journal of Psychopathology and Behavioral Assessment, 28*, 23–32.

American Academy of Pediatrics Committee on Quality Improvement, Subcommittee on Attention-Deficit/Hyperactivity Disorder. (2000). Clinical practice guideline: diagnosis and evaluation of the child with attention-deficit/hyperactivity disorder. *Pediatrics, 105*(5), 1158-1170.

American Educational Research Association (AERA), American Psychological Association, & National Council on Measurement in Education. (1999). Standards for educational and psychological testing. Washington, DC: American Educational Research Association.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (revised 4th ed.). Washington, DC: Author.

Aston-Jones, G., Rajkowski, J., & Cohen J. (1999). Role of locus coeruleus in attention and behavioral flexibility. *Biological Psychiatry, 46*, 1309–1320.

Atchison, B. J. (2007). Sensory modulation disorders among children with a history of trauma: A frame of reference for speech pathologists. *Language, Speech, and Hearing Services in Schools*, *38,* 109-116.

Ayres, A. J. (1972). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy*, *26,* 13-18.

Ayres, A. J. & Tickle, L. S. (1980). Hyper-responsivity to touch and vestibular stimuli as a predictor of positive response to sensory integration procedures by autistic children. *American Journal of Occupational Therapy, 34*, 375-381.

Backonja, M. M., Walk, D., Edwards, R. R., Sehgal, N., Moeller-Bertram, T., Wasan, A., Irving, G., Argoff, C., & Wallace M. (2009). Quantitative testing in measurement of neuropathic pain phenomena and other sensory abnormalities. *The Clinical Journal of Pain, 25*, 641-647.

Bar-Shalita, T., Vatine, J. J., Seltzer, Z., & Parush, S. (2009). Psychophysical correlates in children with sensory modulation disorder (SMD). *Physiological Behavior, 98*, 631-639.

Baranek, G. T. (1999). Autism during infancy: A retrospective video analysis of sensory motor gating and social behaviors at 9-12 months of age. *Journal of Autism and Developmental Disorders, 29*, 213-224.

Baranek, G. T., & Berkson, G. (1994). Tactile defensiveness in children with developmental disabilities: Responsiveness and habituation. *Journal of Autism and Developmental Disorders*, *24*, 457-471.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory experiences questionnaire. Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, 47,* 591-601.

Baranek, G. T., Foster, L. G., & Berkson, G. (1997). Tactile defensiveness and stereotyped behaviors. *American Journal of Occupational Therapy, 51,* 91-95.

Barkley, R. A. (1997a). *ADHD and the nature of self-control.* New York, NY: Guilford Press.

Barkley, R. A. (1997b). Behavioral inhibition, sustained attention, and executive function: Constructing a unified theory of ADHD. *Psychological Bulletin, 121,* 65–94.

Barkley, R. (2000). *Taking charge of ADHD: The complete, authoritative guide for parents* (Rev. ed.). New York, NY: Guilford Press.

Barkley, R. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Developmental Psychopathology, 17,* 807-825.

Barkley, R. A. (2006). Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment (3rd ed.). New York, NY: Guilford Press.

Barkley, R. A., Koplowicz, S., Anderson, T., & McMurray, M.B. (1997). Sense of time in children with ADHD: Two preliminary studies. *Journal of the International Neuropsychological Society, 3,* 359-369.

Barkley, R., & Murphy, K. (1998). *Attention-deficit hyperactivity disorder: A clinical workbook* (2nd ed.). New York, NY: Guilford Press.

Barkley, R., Murphy, K., & Fischer, M. (2008). ADHD in Adults: What the Science Says (pp 171 - 175). New York, NY, Guilford Press.

Bast, T., & Feldon, J. (2003). Hippocampal modulation of sensorimotor processes. *Progress in Neurobiology, 70*(4), 319-345.

Ben-Sasson, A., Cermak, S., Orsmond, G., Carter, A., & Fogg, L. (2007). Can we differentiate sensory over-responsivity from anxiety symptoms in toddlers? Perspectives of occupational therapists and psychologists. *Infant Mental Health Journal, 28,* 536-558. doi:10.1002/imhj.20152

Biederman, J., Faraone, S.V., & Monuteaux, M.C. (2002). Differential effect of environmental adversity by gender: Rutter's index of adversity in a group of boys and girls with and without ADHD. *American Journal of Psychiatry, 159,* 1556–1562.

Bitsakou, P., Psychogiou, L., Thompson, M., & Sonuga-Barke, E. J. S. (2009). Delay aversion inattention deficit/hyperactivity disorder: An empirical investigation of the broader phenotype. *Neuropsychologia, 47,* 446-456.

Boonstra, A., Kooij, J., Oosterlaan, J., Sergeant, J. A., & Buitelaar, J. K. (2010). To act or not to act, that's the problem: Primarily inhibition difficulties in adult ADHD. *Neuropsychology, 24*(2), 209-221. doi:10.1037/a0017670

Borger N., & Van der Meere J. (2000). Visual behaviour of ADHD children during an attention test: An almost forgotten variable. Attention-deficit hyperactivity disorder. *Journal of Child Psychology and Psychiatry, 41*, 525–532.

Breedlove, M., Rosenzweig, M., & Watson, N. (2007). *Biological psychology: An introduction to behavioral, cognitive, and clinical neuroscience* (5th ed.). New York, NY: Harper.

Brieber, S., Neufang, S., & Bruning, N. (2007). Structural brain abnormalities in adolescents with autism spectrum disorder and patients with attention eficit/hyperactivity disorder. *Journal of Child Psychology and Psychiatry, 48*, 1251–1258.

Brown, C. E., & Dunn, W. (2002). Adolescent/adult sensory profile. San Antonio, TX: Harcourt Assessment Company.

Brown, T. E. (2001). Brown attention deficit disorder scales for children and adolescents (2nd ed.). San Antonio, TX: The Psychological Corporation.

Burns, G., Gomez, R., Walsh, J. A., & Moura, M. (2003). Understanding source effects in ADHD rating scales: Reply to DuPaul (2003). *Psychological Assessment*, *15*(1), 118-119. doi:10.1037/1040-3590.15.1.118

Burns, G. L., & Haynes, S. N. (2006). Clinical psychology: Construct validation with multiple sources of information and multiple settings. In M. Eid & E. Diener (Eds.), *Handbook of multimethod measurement in psychology* (pp. 401-418). Washington, DC: American Psychological Association.

Busse, R. T., & Beaver, B. R. (2000). Informant reports: Parent and teacher interviews. In E. S. Shapiro & T. R. Kratochwill (Eds.), *Conducting school-based assessments of child and adolescent behavior.* pp. 235-273. New York, NY: Guilford Press.

Carter, A. S., Ben-Sasson, A., & Briggs-Gowan, M. J. (2011). Sensory over-responsivity, psychopathology, and family impairment in school age children. *Journal of the American Academy of Child and Adolescent Psychiatry, 50,* 1210-1219.

Case-Smith, J. (2005). *Occupational therapy for children* (5th ed.). St. Louis, MO: Elsevier.

Casey, B. J. (2001). Disruption of inhibitory control in developmental disorders: A S. Siegler (Eds.), *Mechanisms of cognitive development: Behavioral and neural perspectives* (pp. 327- 349). Mahwah, NJ: Earlbaum.

Castellanos, F. X., Lee, P. P., & Sharp, W. (2002). Developmental trajectories of brain volume abnormalities in children and adolescents with attention-deficit/hyperactivity disorder. *Journal of American Medical Association, 288,* 1740–1748.

Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: Beyond executive dysfunction. *Trends in Cognitive Sciences*, *10*(3), 117–123.

Castellanos, F. X., & Tannock, R. (2002). Neuroscience of attention deficit/hyperactivity disorder: The search for endophenotypes. *Neuroscience, 3,* 617–628.

Cermak, S. A., & Daunhauer, L. A. (1997). Sensory processing in the post institutionalized child. *American Journal of Occupational Therapy, 51*, 500-507.

Cermak, S. A., & Miller, L. (2005). The relation between length of institutionalization and sensory integration in children adopted from Eastern Europe. *American Journal of Occupational Therapy*, *59,* 139-147.

Chang, D. F., & Stanley, S. (2003). The effects of race and problem type on teachers' assessments of student behavior. *Journal of Consulting and Clinical Psychology, 71*, 235-242. doi: 10.1037/0022-006X.71.2.235

Cheng, M., & Boggett-Carsjens, J. (2005, May). Consider sensory processing disorders in the explosive child: Case report and review. *The Canadian Child And Adolescent Psychiatry Review = La Revue Canadienne De Psychiatrie De L'enfant Et De L'adolescent*, *14*(2), 44-48.

Cherkasova, M. V., & Hechtman, L. (2009). Neuroimaging in attention-deficit hyperactivity disorder: Beyond the frontostriatal circuitry. *Canadian Journal of Psychiatry*, *54*, 651-664.

Cheung, P. P., & Siu, A. M. (2009). A comparison of patterns of sensory processing in children with and without developmental disabilities. *Research in Developmental Disabilities, 30*, 1468-1480.

Chow, S. (2005). The suitability of the Sensory Profile for diagnosing sensory modulation dysfunctions in Chinese children. *International Journal of Rehabilitation Research, 28*, 153-158.

Connors, C. K. (2008). *Connors' 3rd edition.* Toronto, Ontario, Canada: Multi Health Systems.

Corcoran, K., & Fischer, J. (2000). *Measures for clinical practice: A sourcebook* (3rd ed.) (Vols. 1-2). New York, NY: Free Press.

Cox, A., Gast, D., Luscre, D., & Ayres, K. (2009). The effects of weighted vests on appropriate in-seat behaviors of elementary-age students with autism and severe to profound intellectual disabilities. *Focus on Autism and Other Developmental Disabilities, 24*(1), 17-26.

Craske, M. G. (2003). *Origins of phobias and anxiety disorders: Why more women than men?* Oxford: Elsevier.

Crepeau-Hobson, A. (2009). The relationship between perinatal risk factors and sensory processing difficulties in preschool children. *Journal of Developmental and Physical Disabilities, 21,* 315-328. doi: 10.1007/s10882-009-9144-x

Crystal, D. S., Ostrander, R., Chen, R. S., & August, G. J. (2001). Multimethod assessment of psychopathology among DSM–IV subtypes of children with attention-deficit/hyperactivity disorder: Self-, parents and teacher reports. *Journal of Abnormal Child Psychology*, *29*, 189–206.

Cuffe, S., Moore, C., & McKeown, R. (2005). Prevalence and correlates of ADHD symptoms in the National Health Interview Survey. *Journal of Attention Disorders, 9,* 392-401.

Davies, P. L., Chang, W. P., & Gavin, W. J. (2009). Maturation of sensory gating performance in children with and without sensory processing disorders. *International Journal of Psychophysiology*, *72*, 187-197. doi:10.1016/j.ijpsycho.2008.12.007

Davies, P. L., & Gavin W. J. (2007). Validating the diagnosis of sensory processing disorders using EEG technology. *American Journal of Occupational Therapy, 6,* 176–189.

Davis, M. (1992). The role of the amygdala in fear and anxiety. *Annual Review of Neuroscience, 15*, 353–375.

De Gelder, B., Vroomen, J., Annen, L., Masthof, E., & Hodiamont, P. (2003). Audio-visual integration in schizophrenia. *Schizophrenia Research, 59* (2–3*),* 211–218.

Demaray, M. K., Schaefer, K., & Delong, L. (2003). Attention-deficit/hyperactivity disorder (ADHD): A national survey of training and current assessment practices in the schools. *Psychology in the Schools, 40*, 583-597. Doi: 10.1002/pits.10129

De Wilde, O. M., Bour, L. J., Dingemans, P. M., Koelman, J. H., & Linszen, D. H. (2007). A meta-analysis of P50 studies in patients with schizophrenia and relatives: Differences in methodology between research groups. *Schizophrenia Research, 97*, 137–151.

Doyle, A. E. (2006). Executive functions in attention-deficit/hyperactivity disorder. *Journal of Clinical Psychiatry, 67,* 21-26.

Dunn, W. (1997). The impact of sensory processing abilities on the lives of young children: A conceptual model. *Infants & Young Children, 9,* 23-35.

Dunn, W. (1999). Sensory Profile. San Antonio, TX: The Psychological Corporation.

Dunn, W. (2002). The infant/toddler sensory profile. San Antonio, TX: The Psychological Corporation.

Dunn, W. (2006). Sensory Profile School Companion.

Dunn, W. & Bennett, D. (2002). Patterns of sensory processing in children with attention deficit hyperactivity disorder. *Occupational Therapy Journal of Research, 22*, 4–15.

DuPaul, G. J. (2003). Assessment of ADHD symptoms: Comment on Gomez et al. (2003). *Psychological Assessment, 15,* 115–117.

DuPaul, G. J., Power, T. J., Anastopoulos, A. D., & Reid, R. (1998). ADHD Rating Scale-IV: Checklists, norms, and clinical interpretation. New York, NY: Guilford Press.

DuPaul, G. J., & Stoner, G. (2003). *ADHD in the schools: Assessment and intervention strategies* (2nd ed.). New York, NY: Guilford Press.

Elliott, R., Friston, K. J., & Dolan, R. J. (2000). Dissociable neural responses in human reward systems. *Journal of Neuroscience, 20,* 6159–6165.

Ernst, M., Bolla, K., & Mouratidis, M. (2002). Decision-making in a risk-taking task: A PET study. *Neuropsychopharmacology, 26,* 682–691.

Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 367- 395). Baltimore, MD: Brooks.

Fiske, D. W. (1987). Construct invalidity comes from method effects. *Educational and Psychological Measurement, 47,* 285–336.

Fortin, N. J., Agster, K. L., & Eichenbaum, H. B. (2002). Critical role of the hippocampus in memory for sequences of events. *National Neuroscience 5,* 458–462.

Friedman-Hill, S. R., Wagman, M. R., Gex, S. E., Pine, D. S., Leibenluft, E., & Ungerleider, L. G. (2010). What does distractibility in ADHD reveal about mechanisms for top-down attentional control? *Cognition, 115(1),* 93-103.

Frodl, T. T., Stauber, J. J., Schaaff, N. N., Koutsouleris, N. N., Scheuerecker, J. J., Ewers, M. M., & Meisenzahl, E. E. (2010). Amygdala reduction in patients with ADHD compared with major depression and healthy volunteers. *Acta Psychiatrica Scandinavica, 121,* 111-118. doi:10.1111/j.1600-0447.2009.01489.x

Gomez, R., Burns, G. L., Walsh, J. A., & Moura, M. A. (2003). A multitrait-multisource factor analytic approach to the construct validity of ADHD rating scales. *Psychological Assessment, 15,* 3–16.

Grandin, T. (1992). Calming effects of deep touch pressure in patients with autistic disorder, college students, and animals. *Journal of Child and Adolescent Psychopharmacology, 2*(1), 63-72.

Green, S. A., & Ben-Sasson, A. (2010). Anxiety disorders and sensory over-responsivity in children with autism spectrum disorders: Is there a causal relationship? *Journal of Autism and Developmental Disorders, 40*(12), 1495-1504.

Greenbaum, P. E., Dedrick, R. F., Prange, M. E., & Friedman, R. M. (1994). Parent, teacher, and child ratings of problem behaviors of youngsters with serious emotional disturbances. *Psychological Assessment, 6,* 141–148.

Greenspan, S., & Porges, S. (1984). Psychopathology in infancy and early childhood: Clinical perspectives on the organization of sensory and affective-thematic experience. *Child Development*, *55*(1), 49-70.

Griskova, I., & Arnfred, S. M. (2008). An electrophysiological approach to investigations of sensory dysfunction in schizophrenia. *Poiesis and Praxis, 6*, 175-189.

Hale, J. B., Reddy, L. A., Semrud-Clikeman, M., Hain, L., Whitaker, J., Morley, J., . . . Jones, N. (2011). Executive impairment determines ADHD medication response: Implications for academic achievement. *Journal of Learning Disabilities*, *44*, 196-212.

Hanft, B., Miller, L. J., & Lane, S. (2000) Toward a consensus in terminology in sensory integration theory and practice: Part 3. Sensory integration dysfunction. *Sensory Integration Special Interest Section Quarterly*, *23*(3), 1-4.

Hetrick, W. P., Sandman, C. A., Bunney, W. E., Jr., Jin, Y., Potkin, S. G., & White, M. H. (1996). Gender differences in gating of the auditory evoked potential in normal subjects. *Biological Psychiatry, 39,* 51–58.

Hosterman, S. J., DuPaul, G. J., & Jitendra, A. K. (2008). Teacher ratings of ADHD symptoms in ethnic minority students: Bias or behavioral difference? *School Psychology Quarterly, 23*(3), 418-435.

Hyatt, K., Stephenson, J., & Carter, M. (2009). A review of three controversial educational practices: Perceptual motor programs, sensory integration, and tinted lenses. *Education & Treatment of Children, 32*, 313-342.

Itsakou, P. P., Psychogiou, L. L., Thompson, M. M., & Sonuga-Barke, E. S. (2009). Delay aversion in attention deficit/hyperactivity disorder: An empirical investigation of the broader phenotype. *Neuropsychologia, 47,* 446-456. doi:10.1016/j.neuropsychologia.2008.09.015

Ivanov, I., Bansal, R., Hao, X., Zhu, H., Kellendonk, C., Miller, L., & ... Peterson, B. (2010). Morphological abnormalities of the thalamus in youths with attention deficit hyperactivity disorder. *American Journal of Psychiatry, 167,* 397-408. doi:10.1176/appi.ajp.2009.09030398

James, K., Miller, L. J., Schaaf, R., Nielson, D. M., & Schoen, S. (2011). Phenotypes within sensory modulation dysfunction. *Comprehensive Psychiatry 52*, 715–724.

Johnson, K. L, Nicol, T. G., Zecker, S. G., & Kraus, N. (2007). Auditory brainstem correlates of perceptual timing deficits. *Journal Cognitive Neuroscience, 19,* 376–385.

Kane, M. J, Bleckley, M. K., Conway, A. R. A, & Engle R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology, 130,* 169 –183.

Kawamura, H. (2009). Why the SCN influences the whole body: Role of the hypothalamus and reticular activating system. *Sleep & Biological Rhythms, 7,* 224-225. doi:10.1111/j.1479-8425.2009.00429.x

Kelly, K. G., Cook, T., & Backonja, M. M. (2005). Pain ratings at the thresholds are necessary for interpretation of quantitative sensory testing. *Muscle Nerve, 32,* 179–184.

Kieling, C., Goncalves, R. R., Tannock, R., & Castellanos, F.X. (2008). Neurobiology of attention deficit hyperactivity disorder. *Child Adolescent Psychiatry Clinics of North America, 17*(2), 285-307.

Kim, B. N., Lee, J. S., & Shin, M. S. (2002). Regional cerebral perfusion abnormalities in attention deficit/hyperactivity disorder. *European Archives of Psychiatry and Clinical Neuroscience, 252,* 219–225.

Kinnealey, M. (1973). Aversive and nonaversive responses to sensory stimulation in mentally retarded children. *American Journal of Occupational Therapy*, *27,* 464-472.

Knutson, B., Adams, C. M., Fong, G. W., & Hommer, D. (2002). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience, 22,* 3303-3305.

Koziol, L., Budding, D., & Chidekel, D. (2011). Sensory integration, sensory processing, and sensory modulation disorders: Putative functional neuroanatomic underpinnings. *Cerebellum, 10,* 770-792. doi:10.1007/s12311-011-0288-8

Kumari, V., & Postma, P. (2005). Nicotine use in schizophrenia: The self-medication hypotheses. *Neuroscience and Biobehavioral Reviews, 29*, 1021–1034.

Kypriotaki, M., & Manolitsis, G. (2010). Teachers' evaluations for the detection of primary-school children with attention deficit hyperactivity disorder. *European Journal of Special Needs Education*, *25*(3), 269-281. doi:10.1080/08856257.2010.492940

Lahey, B. B., Pelham, W. E., Loney, J., Lee, S., & Wilcutt, E. G. (2005). Instability of the DSM-IV subtypes of ADHD from preschool through elementary school. *Archives of General Psychiatry 62,* 896–902.

Lambek, R., Tannock, R., Dalsgaard, S., Trillingsgaard, A., Damm, D., & Thomsen, P. (2010). Validating neuropsychological subtypes of ADHD: How do children with and without an executive function deficit differ? *Journal of Child Psychology & Psychiatry*, *51*, 895-904. doi:10.1111/j.1469-7610.2010.02248.x

Lane, S., Lynn, J., & Reynolds, S. (2010). Sensory modulation: A neuroscience and behavioral overview. *OT Practice, 15*(21), CE-1--CE-8.

Lane, S., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience, 4*(8), 1-11. doi:10.3389/fnint.2010.00008

Larson, K. A. (1982). The sensory history of developmentally delayed children with and without tactile defensiveness. *American Journal of Occupational Therapy, 36,* 590-596.

Lijffijt, M., Moeller, F., Boutros, N. N., Burroughs, S., Lane, S. D., Steinberg, J. L., & Swann, A. C. (2009). The role of age, gender, education, and intelligence in P50, N100, and P200 auditory sensory gating. *Journal of Psychophysiology*, 23(2), 52-62. doi:10.1027/0269-8803.23.2.52

Lin, S. (2003). Sensory integration, growth, and emotional and behavioral regulation in adopted post-institutionalized children. *The Sciences and Engineering, 64*(3-B), 1478.

Lin, S., Cermak, S., Costner, W., & Miller, L. (2005). The relation between length of institutionalization and sensory integration in children adopted from Eastern Europe. *American Journal of Occupational Therapy*, *59,* 139-147.

Ludolph, A. G., Pinkhardt, E. H., & Tebartz Van Elst, L. (2008). Are amygdalar volume alterations in children with Tourette syndrome due to ADHD comorbidity? *Developmental Medicine and Child Neurology, 50,* 524–529.

Luman, M., Oosterlaan, J., & Sergeant, J. A. (2005). The impact of reinforcement contingencies on AD/HD: A review and theoretical appraisal. *Clinical Psychology Review, 25*, 183– 213.

Mangeot, S., Miller, L., McIntosh, D., McGrath-Clarke, J., Simon, J., Hagerman, R., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit- hyperactivity disorder. *Developmental Medicine and Child Neurology, 43,* 399- 406.

Marco, R., Miranda, A., Schlotz, W., Melia, A., Mulligan, A., Müller, U., & ... Sonuga-Barke, E. S. (2009). Delay and reward choice in ADHD: An experimental test of the role of delay aversion. *Neuropsychology, 23,* 367-380. doi:10.1037/a0014914

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44,* 377-384.

McAlonan, G. M., & Cheung, C. (2007). Mapping brain structure in attention deficit-hyperactivity disorder: A voxel-based MRI study of regional grey and white matter volume. *Psychiatry Research, 154,* 171–180.

McIntosh, D. N., Miller, L. J., & Shyu, V. (1999). Development and validation of the Short Sensory Profile. In W. Dunn (Ed.), *Sensory Profile Manual* (pp. 59–73). San Antonio, TX: Psychological Corporation.

McIntosh, D. N., Miller, L. J., Shyu, V., & Hagerman, R. J. (1999). Sensory modulation disruption, electrodermal responses, and functional behaviors. *Developmental Medicine and Child Neurology, 41,* 608-615.

Milich, R., Balentine, A., & Lynam, D. R. (2001). ADHD combined type and ADHD predominantly inattentive type are distinct and unrelated disorders. *Clinical Psychology: Science and Practice, 8*, 463–488.

Miller, L. J. (2006). *Sensational kids: Hope and help for children with sensory processing disorder*. New York, NY: Putnam.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy*, *61*(2), 135-140.

Miller, L. J., McIntosh, D. N., McGrath, J., Shyu, V., Lampe, M., Taylor, A.K., et al. (1999). Electrodermal responses to sensory stimuli in individuals with fragile X syndrome: A preliminary report. *American Journal of Medical Genetics*, *83*, 268-279.

Miller, L. J., Milberger, S., & McIntosh, D. (2004). Prevalence of parents perceptions of sensory processing disorders among kindergarten children. *The American Journal of Occupational Therapy*, *58*(3), 287-293.

Miller, L. J., Reisman, J. E., McIntosh, D. N., & Simon, J. (2001). An ecological model of sensory modulation: Performance of children with fragile X syndrome, autistic disorder, attention deficit/hyperactivity disorder, and sensory modulation dysfunction. In S. Smith Roley, E. I. Blanche & R. C. Schaaf (Eds.), *Understanding the nature of sensory integration with diverse populations* (pp. 57-88). San Antonio, TX: Therapy Skill Builders.

Miller, T. W., Nigg, J. T., & Miller, R. L. (2009). Attention deficit hyperactivity disorder in African American children: What can be concluded from the past ten years? *Clinical Psychology Review*, *29*(1), 77-86. doi:10.1016/j.cpr.2008.10.001

Murray, M., Baker, P., Murray-Slutsky, C., & Paris, B. (2009, June 1). Strategies for supporting the sensory-based learner. *Preventing School Failure*, *53*(4), 245-251.

Murray-Slutsky, C., & Paris, B. (2005). *Is it sensory or is it behavior?* San Antonio, TX: Harcourt.

Myers, K., & Winters, N. C. (2002). Ten-year review of rating scales. II: Scales for internalizing disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 41*, 634–659.

Nackley, V. (2001). Sensory diet applications and environmental modifications: A winning combination. *Sensory Integration Special Interest Quarterly, 24*(1), 1-4.

National Association of School Psychologists. (2005, November). Diagnosis and Treatment of Attention Disorders: Roles for School Personnel. Retrieved from http://www.nasponline.org/resources/factsheets/add_fs.aspx

Neal, A. M., & Turner, S. M. (1991). Anxiety disorders research with African Americans: Current status. *Psychological Bulletin, 109*, 400-410. doi:10.1037/0033-2909.109.3.400

Neuman, A. (2006). Patterns of response to sensory stimuli encountered in daily activities: A comparison between 3–10-year-old Israeli and American children without disabilities. *Occupational Therapy International*, *13*(2), *79-99*. doi:10.1002/oti.9

Nigg, J., Willcutt, E., Doyle, A., & Sonuga-Barke, E. (2005). Causal heterogeneity in attention-deficit hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry, 57*, 1224–1230.

Nigg, J. T., Blaskey, L., Stawikcki, J., & Sachek, J. (2004). Evaluating endophenotype model of ADHD neuropsychological deficit: Results for parents and siblings of children with DSM-IV ADHD combined and inattentive subtypes. *Journal of Abnormal Psychology, 113*, 614–625.

Nigg, J. T., Tannock, R., & Rohde, L. A. (2010). What is to be the fate of ADHD subtypes? An introduction to the special section on research on the ADHD subtypes and implications for the DSM-V. *Journal of Clinical Child and Adolescent Psychology, 39*, 723-725. doi:10.1080/15374416.2010.517171

Nijmeijer, J., Minderaa, R., Buitelaar, J., Mulligan, A., Hartman, C., & Hoeskstra, P. (2008). Attention-deficit/hyperactivity disorder and social dysfunctioning. *Clinical Psychology Review, 28*, 692-708.

Nolano, M., Provitera, V., Estraneo, A., Selim, M., Caporaso, G., Stancanelli, A., et al. (2008). Sensory deficit in Parkinsons disease: Evidence of a cutaneous denervation. *Brain: A Journal of Neurology, 131*, 1903-1911.

Ognibene, T. C. (2002). Distinguishing Sensory Modulation Dysfunction From Attention-deficit/Hyperactivity Disorder: Sensory Habituation and Response Inhibition Processes. Ann Arbor, MI: ProQuest Information and Learning.

Olson, L. J., & Moulton, H. J. (2004). Occupational therapists reported experiences using weighted vests with children with specific developmental disorders. *Occupational Therapy International*, *11*(1), 52-66.

Oosterlan, J., Logan, G. D., & Sergeant, J. A. (1998). Response inhibition in AD/HD, CD, comorbid AD/HD +CD, anxious, and control children: A meta-analysis of studies with the stop task. *Journal of Child Psychology and Psychiatrity*, *39*, 411-425.

Parham, L. D., Ecker, C., Kuhaneck, H. M., Henry, D. A., & Glennon, T. J. (2006). *Sensory processing measure*. Los Angeles, CA: Western Psychological Services.

Parham, L. D., & Mailloux, Z. (1996). Sensory integration. In J. Case-Smith, A. Allen, & P. Pratt (Eds.), *Occupational therapy for children*, (3rd ed.). (pp. 307-356). New York, NY: Mosby.

Parham, L. D., & Mailloux, Z. (2005). Sensory integration. In J. Case-Smith (Ed.), *Occupational therapy for children* (5th ed.) pp 356-411. St. Louis, MO: Elsevier.

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (1997). Somatosensory functioning in children with attention deficit hyperactivity disorder. *Developmental Medicine and Child Neurology, 39*, 464-468.

Patterson, J. V., Hetrick, W. P., Boutros, N. N., Jin, Y., Sandman, C., Stern, H. et al. (2008). P50 sensory gating ratios in schizophrenics and controls: A review and data analysis. *Psychiatry Research, 158*, 226–247.

Pennington, B.F. (1991). Issues in syndrome validation. Diagnosing learning disorders: A neuropsychological framework. New York, NY: Guilford Press: 23-31.

Pennington, B. F. (2002). *The development of psychopathology: Nature and nurture*. New York, NY: Guilford Press.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37,* 51-87.

Piacentini, J. (1993). Checklists and rating scales. In T. H. Ollendick & M. Hersen (Eds.), *Handbook of child and adolescent assessment* (pp. 82–97). Boston, MA: Allyn & Bacon.

Plessen, K. J, Bansal, R., & Zhu, H. (2006). Hippocampus and amygdala morphology in attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 63,* 795–807.

Pliszka, S., Glahn, D., Semrud-Clikeman, M., Franklin, C., Perez, R., III , & Liotti, M. (2006). Neuroimaging of inhibitory control in treatment naive and chronically treated children with ADHD. *American Journal of Psychiatry, 163,* 1052–1060.

Porges, S. W. (1995). Orienting in a defensive world: Mammalian modifications of our evolutionary heritage. A polyvagal theory. *Psychophysiology, 32*, 301-318.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42*, 123-146.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143.

Power, T. J., Costigan, T. E., Leff, S. S., Eiraldi, R. B., & Landau, S. (2001). Assessing ADHD across settings: Contributions of behavioral assessment to categorical decision making. *Journal of Clinical Child Psychology, 30,* 399–412.

Quay, H. C. (1997). Inhibition and attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology, 25*(1), 7-13.

Ramirez, R. & Shapiro, E. S. (2005) Effects of student ethnicity on judgments of ADHD symptoms among Hispanic and White teachers. *School Psychology Quarterly, 20*, 268 – 287.

Rentzsch, J., Jockers-Scherubl, M. C., Boutros, N. N., & Gallinat, J. (2008). Test-retest reliability of P50, N100 and P200 auditory sensory gating in healthy subjects. *International Journal of Psychophysiology*, *67*(2), 81-90.

Reynolds, S., La Rentzsch, J. J., Jockers-Scherubl, M. C., Boutros, N. N., & Gallinat, J. J. (2008). Test-retest reliability of P50, N100 and P200 auditory sensory gating in healthy subjects. *International Journal of Psychophysiology, 67*(2), 81-90. doi:10.1016/j.ijpsycho.2007.10.006

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism and Developmental Disabilities, 38*, 516-529.

Rieke, E., & Anderson, D. (2009). Adolescent/adult sensory profile and obsessive-compulsive disorder. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *63*(2), 138-145.

Rinn, A. N., & Nelson, J. M. (2009). Preservice teachers' perceptions of behaviors characteristic of ADHD and giftedness. *Roeper Review, 31*, 18–26.

Rolke, R., Baron, R., & Maier, C., et al. (2006). Quantitative sensory testing in the German Research Network on Neuropathic Pain (DFNS): Standardized protocol and reference values. *Pain, 123,* 231–243.

Royeen, C. B., & Lane, S. J. (1991). Tactile processing and sensory defensiveness. In A. G. Fisher, E. A. Murray & A. C. Bundy (Eds.), *Sensory integration: Theory and practice.* Philadelphia, PA: F. A. Davis.

Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. (2005). A dynamic developmental theory of attention-deficit/hyperactivity disorder (ADHD) predominantly hyperactive/impulsive and combined subtypes. *Behavioural and Brain Sciences, 28,* 397–419.

Sagvolden, T., & Sergeant, J. A. (1998). Attention deficit-hyperactivity disorder: From brain dysfunctions to behaviour. *Behavioural Brain Research, 94,* 1-10.

Satiansukpong, N. (2002). *Reliability and validity of Dunn's Sensory Profile among Thai children living in large metropolitan areas* (Doctoral dissertation).

Satterfield, J. H., & Dawson, M. E. (1971). Electrodermal correlates of hyperactivity in children. *Psychophysiology, 8,* 191-197.

Schaaf, R. C. (2001). Parasympathetic nervous system functions in children with sensory modulation dysfunction: A preliminary study. *Bell and Howell Information and Learning,* 1-70.

Schaaf, R. C., Benevides, T., Blanche, E., Brett-Green, B. A., Burke, J. P., Cohn, E. S., & Schoen, S. A. (2010). Parasympathetic functions in children with sensory processing disorder. *Frontiers in Integrative Neuroscience, 4,* 1-11. doi:10.3389/fnint.2010.00004

Schachar, R.J., Tannock, R., & Logan, G.D. (1993). Inhibitory control, impulsiveness, and attention deficit hyperactivity disorder. *Clinical Psychology Review, 13,* 721-739.

Schneider, M., Moore, C., Gajewski, L., Laughlin, N., Larson, J., Gay, C., . . . DeJesus, O. (2008). Sensory processing disorder in a primate model: Evidence from a longitudinal study of prenatal alcohol and prenatal stress effects. *Child Development, 79*, 100-113. doi:10.1111/j.1467-8624.2007.01113.x

Schoen, S., Miller, L. J., & Green, K. E. (2005). *The sensory over-responsivity assessment and inventory: Reliability and validity*. Unpublished manuscript, University of Colorado Health Science Center.

Schoen, S. A., Miller, L. J., & Green, K. (2008). A pilot study of the Sensory Over-Responsivity Scales: Assessment and inventory. *American Journal of Occupational Therapy, 62*, 393–406.

Schulze, K. K., Hall, M., McDonald, C., Marshall, N., Walshe, M., Murray, R.M., & Bramon, E. (2007). P50 auditory evoked potential suppression in bipolar disorder patients with psychotic features and their unaffected relatives. *Biological Psychiatry, 62,* 121–128.

Sciutto, M. J., Terjesen, M. D., & Bender-Frank, A. S. (2000). Teachers' knowledge and misperceptions of attention-deficit/hyperactivity disorder. *Psychology in the Schools, 37(2),* 115–122.

Semrud-Clikeman, M., Pliszka, S., & Liotti, M. (2008). Executive functioning in children with attention-deficit/hyperactivity disorder: Combined type with and without a stimulant medication history. *Neuropsychology*, *22,* 329-340. doi:10.1037/0894-4105.22.3.329

Semrud-Clikeman, M., Plizska, S., Liotti, M., Higgins, K., & Lancaster, J. L. (2006). Neuroimaging in children with ADHD, treated and treatment naıve. *Neurology, 67,*1023–1027.

Sergeant, J. A. (2005). Modeling attention-deficit/hyperactivity disorder: A critical appraisal of the cognitive-energetic model. *Biological Psychiatry, 57,* 1248–1255.

Sergeant, J. A., Geurts, H., Huijbregts., S., Scheres, A., & Oosterlaan, J. (2003). The top and the bottom of ADHD: A neuropsychological perspective. *Neuroscience and Biobehavioral Reviews, 27,* 583–592.

Shaffer, D., Fisher P., Lucas, C. P., Dulcan, M. K., & Schwab-Stone, M. E. (2000). NIMH Diagnostic Interview Schedule for Children Version IV (NIMH DISC-IV): Description, differences from previous versions, and reliability of some common diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 28-38.

Shanahan, M. A., Pennington, B. F., & Willcutt, E. W. (2008). Do motivational incentives reduce the inhibition deficit in ADHD? *Developmental Neuropsychology, 33,* 137-159. doi:10.1080/87565640701884238

Shaw, P., Eckstrand, K., Sharp, W., Blumenthal, J., Lerch, J. P., Greenstein, D., … Rapoport, J. L. (2007). Attention-deficit ⁄ hyperactivity disorder is characterized by a delay in cortical maturation. *Proceedings of the National Academy of Sciences of the United States of America, 104,* 19649–19654.

Shaw, P., Lerch, J., & Sharp, W. (2006). Longitudinal mapping of cortical thickness and clinical outcome in children and adolescents with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 63,* 540–549.

Shelton, T. L., & Barkley, R. A. (1994). Critical issues in the assessment of attention-Deficit disorders in children. *Topics in Language Disorders, 14*(4), 26-41.

Sobanski, E. (2006). Psychiatric comorbidity in adults with attention-deficit/hyperactivity disorder (ADHD). *European Archives of Psychiatry Clinical Neuroscience, 256*(3), 26-31.

Solanto, M. V., Abikoff, H., Sonuga-Barke, E., Schachar, R., Logan, G. D., Wigal, T., . . . Turkel, E. (2001). The ecological validity of delay version and response inhibition as measures of impulsivity in ADHD: A supplement to the NIMH multimodal treatment study of ADHD. *Journal of Abnormal Child Psychology, 29,* 215–228.

Sonuga-Barke, E. J. S. (2002). Psychological heterogeneity in AD/HD: A dual pathway model of behaviour and cognition. *Behavior Brain Research, 130*, 29-36.

Sonuga-Barke, E. J. S., Taylor, E., Sembi, S., & Smith, J. (1992). Hyperactivity and delay aversion I: The effect of delay on choice. *Journal of Child Psychology and Psychiatry, 33,* 387–398.

Sonuga-Barke, E. J. S., De Houwer, J., De Ruiter, K., Azensten, M., & Holland, S. (2004). ADHD and the capture of attention by briefly exposed delay-related cues. Evidence from a conditioning paradigm. *Journal of Child Psychology and Psychiatry, 45*, 274–283.

Sonuga-Barke, E. J. S., Sergeant, S., Nigg, J., & Willcutt, E. (2008). Executive dysfunction and delay aversion in ADHD: Nosological and diagnostic implications. *North American Clinics in Child & Adolescent Psychiatry, 17,* 367–384.

Sonuga-Barke, E. J. S. (2005). Causal models of attention-deficit/hyperactivity disorder: From common simple deficits to multiple developmental pathways. *Biological Psychiatry, 57*, 1231-1238.

Spencer, T. J., Biederman, J., & Mick, E. (2007). Attention-deficit/hyperactivity disorder: Diagnosis, lifespan, comorbidities, and neurobiology. *Journal of Pediatric Psychology, 32*, 631-642.

Steinhausen, H. C. (2009). The heterogeneity of causes and courses of attention-deficit/hyperactivity disorder. *Acta Psychiatrica Scandinavica*, *120*, 392-399. doi:10.1111/j.1600-0447.2009.01446.x

Talay-Ongan, A., & Wood, K. (2000). Unusual sensory sensitivity in autism: A possible crossroad. *International Journal of Disability, Development and Education, 47,* 201-212.

Tannock, R. (1998). Attention deficit hyperactivity disorder: Advances in cognitive, neurobiological and genetic research. *Journal of Child Psychology and Psychiatry, 39,* 65–99.

Tucker, C., & Dixon, A. L. (2009). Low-income African American male youth with ADHD symptoms in the United States: Recommendations for clinical mental health counselors. *Journal of Mental Health Counseling, 31*(4), 309-322.

Vaidya, C. J., & Stollstorff, M. (2008). Cognitive neuroscience of attention deficit hyperactivity disorder: Current status and working hypotheses. *Developmental Disabilities Research Reviews, 14,* 261-267. doi:10.1002/ddrr.40

Valera, E. M., Faraone, S. V., Murray, K. E., & Seidman, L. J. (2007). Meta-analysis of structural imaging findings in attention-deficit/hyperactivity disorder. *Biological Psychiatry, 61*, 1361–1369.

Vance, A. L. A., Maruff, P., & Barnett, R. (2003). Attention deficit hyperactivity disorder, combined type: Better executive function performance with longer-term psychostimulant medication. *Australian and New Zealand Journal of Psychiatry, 37,* 570–576.

Van der Meere, J., Börger, N. A., & Wiersema, J. R. (2010). ADHD: State regulation and motivation. *Current Medical Literature: Psychiatry, 21*(1), 14-20.

Van Der Meere, J., & Stemerdink, N. (1999). The development of state regulation in normal children: an indirect comparison with children with ADHD. *Developmental Neuropsychology*, *16*(2), 213-225. Retrieved from http://www.tandfonline.com/doi/abs/10.1207/S15326942DN1602_5

Waldo, M. C., Graze, K., de Graff Bender, S., Adler, L. E., & Freedman, R. (1987). Premenstrual mood changes and gating of the auditory evoked potential. *Psychoneuroendocrinology, 12*, 35–40.

Wang, J., Miyazato, H., Hokama, H., Hiramatsu, K., & Kondo, T. (2004). Correlation between P50 suppression and psychometric schizotypy among nonclinical Japanese subjects. *International Journal of Psychophysiology, 52*, 147–157.

White, P. M., Kanazawa, A., & Yee, C. M. (2005). Gender and suppression of mind-latency ERP components during stress. *Psychophysiology, 42,* 720–725.

Wilbarger, J., Gunnar, M., Schneider, M., & Pollak, S. (2010). Sensory processing in internationally adopted, post-institutionalized children. *Journal of Child Psychology and Psychiatry, 51*, 1105-1114.

Willcutt, E. G., & Carlson, C. L. (2005). The diagnostic validity of ADHD. *Journal of Clinical Neuroscience Research*, *5,* 219-230.

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of ADHD: A meta-analytic review. *Biological Psychiatry, 57*, 1224–1230.

Willcutt, E. G., Pennington, B. F., Chhabildas, N. A., Friedman, M. C., & Alexander, J. (1999). Psychiatric comorbidity associated with DSM-IV ADHD in a nonreferred sample of twins. *Journal of the American Academy of Child and Adolescent Psychiatry, 38,* 1355–1362.

Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuro-psychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental Neuropsychology*, *27*, 35–78.

Wolraich M. L., Bard, D. E., Stein, M. T., Rushton J. L., & O'Connor K. G. (2010). Pediatrician's attitudes and practice on ADHD before and after the development of ADHD practice guidelines. *Journal of Attention Disorders, 13*, 563-572.

Woods, G. W., Greensspan, S., & Agarkar, B. S. (2011). Ethnic and cultural factors in identifying fetal alcohol spectrum disorders. *Journal of Psychiatry & Law, 39*(1), 9-37.

Yochman, A., Parush, S., & Ornoy, A. (2004). Responses of pre-school children with and without ADHD to sensory events in daily life. *American Journal of Occupational Therapy, 58*, 294-302.

Zald, D. H. (2003). The human amygdala and the emotional evaluation of sensory stimuli. *Brain Research Reviews, 41*, 88–123.

Zelazo, P. D., & Muller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445–469). Oxford, England: Blackwell.