

OCCUPATIONAL THERAPY USING A SENSORY INTEGRATIVE APPROACH FOR CHILDREN WITH DEVELOPMENTAL DISABILITIES

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This article provides an introduction and overview of sensory integration theory as it is used in occupational therapy practice for children with developmental disabilities. This review of the theoretical tenets of the theory, its historical foundations, and early research provides the reader with a basis for exploring current uses and applications. The key principles of the sensory integrative approach, including concepts such as “the just right challenge” and “the adaptive response” as conceptualized by A. Jean Ayres, the theory’s founder, are presented to familiarize the reader with the approach. The state of research in this area is presented, including studies underway to further delineate the subtypes of sensory integrative dysfunction, the neurobiological mechanisms of poor sensory processing, advances in theory development, and the development of a fidelity measure for use in intervention studies. Finally, this article reviews the current state of the evidence to support this approach and suggests that consensual knowledge and empirical research are needed to further elucidate the theory and its utility for a variety of children with developmental disabilities. This is especially critical given the public pressure by parents of children with autism and other developmental disabilities to obtain services and who have anecdotally noted the utility of sensory integration therapy for helping their children function more independently. Key limiting factors to research include lack of funding, paucity of doctorate trained clinicians and researchers in occupational therapy, and the inherent heterogeneity of the population of children affected by sensory integrative dysfunction. A call to action for occupational therapy researchers, funding agencies, and other professions is made to support ongoing efforts and to develop initiatives that will lead to better diagnoses and effective intervention for sensory integrative dysfunction, which will improve the lives of children and their families. © 2005 Wiley-Liss, Inc. MRDD Research Reviews 2005;11:143–148.

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Occupational therapy with a sensory integration approach (OT/SI) is designed to guide intervention for children who have significant difficulty processing sensory information, which restricts participation in daily life activities. The theory of sensory integration was developed by A. Jean Ayres [Ayres, 1972, 1979, 1989], an occupational therapist with postdoctoral training in educational psychology and neuroscience. Guided by her roots in the clinical field of occupational therapy (OT), Ayres developed the theory of sensory integration to explicate potential relationships between the neural processes of receiving, modulating, and integrating sensory input and the resulting output: adaptive behavior. The theory postulates that adequate processing and integration of sensory

information is an important substrate for adaptive behavior. Given its focus on adaptive behavior and functional skills, this approach is most frequently utilized by occupational therapists as part of a total program of occupational therapy. The goal of intervention is to improve the ability to process and integrate sensory information and to provide a basis for improved independence and participation in daily life activities, play, and school tasks.

HISTORICAL PERSPECTIVES AND NEUROBIOLOGICAL ROOTS

Ayres’ work was prompted by her clinical observations of children with learning disabilities, many of whom she noted displayed perceptual, sensory, and motor difficulties. Hypothesizing that “learning is a function of the brain [and] learning disorders . . . reflect some deviation in neural functions [Ayres, 1972],” Ayres developed a theoretical model, the theory of Sensory Integration (SI). This theory; based on principles from neuroscience, biology, psychology, and education, hypothesizes that some children with learning disorders experience difficulty processing and integrating sensory information and that this, in turn, affects their behavior and learning. She theorized that the behavior and learning problems were, in part, due to faulty integration of sensory information and inability of higher centers to modulate and regulate lower brain sensory–motor centers [Ayres, 1972].

The theory is based on principles from neuroscience, developmental psychology, occupational therapy, and education: 1) sensorimotor development is an important substrate for learning; 2) the interaction of the individual with the environment shapes brain development; 3) the nervous system is capable of change (plasticity); and 4) meaningful sensory–motor activity

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is a powerful mediator of plasticity. Although new findings and knowledge demonstrate that the nervous system is even more complex and integrated than Ayres and others believed at the time, many of the principles that Ayres built the theory of sensory integration upon are still held in high regard. This knowledge has been strengthened by research demonstrating that structural, molecular, and cellular changes in neural functions are possible and that meaningful sensory motor activities can be mediators of plasticity [Merzenich et al., 1984; Greenough et al., 1987; Kandel and Jessell, 1995; Kempermann and Gage, 1999; McKenzie, et al., 2003].

To examine and field test her theory of SI, Ayres created a battery of tests, the Southern California Sensory Integration tests, which evaluated sensory processing, sensory motor, and perceptual motor skills. Using these tests, she conducted a number of cluster and factor analytic studies to further define the theory. She found clusters of symptoms that fell into meaningful patterns that described clinical samples of the children, which served to guide intervention strategies [Ayres, 1979, 1989]. For example, a factor termed “developmental dyspraxia” was consistently identified in children who seemed to have difficulty creating ideas for, planning, and carrying out new motor activities and processing tactile and other somatosensory information.

THE SENSORY INTEGRATIVE APPROACH

Professionals who use the sensory integrative approach follow a set of principles, based on sensory integration theory, that guide the therapists’ clinical reasoning skills. These principles are operationalized in therapy to include concepts such as “Active Sensory–Motor Experiences,” “the Just Right Challenge,” “the Adaptive Response,” “Active Participation,” and “Child–Direction.” These principles are further defined and delineated in Table 1. The intervention is unique in that it addresses the underlying substrates of dysfunction rather than just the functional difficulties itself. Ayres [1972] states:

A sensory integrative approach to treating learning disorders differs from many other approaches in that it does not teach specific skills. . . . Rather, the objective is to enhance the brain’s . . . capacity to perceive, remember, and motor plan [as a basis for learning]. . . . Therapy is considered a supplement, not a substitute to formal classroom instruction. . .

Therapy provides opportunities for engagement in sensory motor activities rich in tactile, vestibular, and propriocep-

Table 1. Key Principles of the Sensory Integrative Approach

Principle	Description
Just Right Challenge	The therapist creates playful activities with achievable challenges; the activities incorporate a challenge but the child is always successful.
The Adaptive Response	In response to the Just Right Challenge, the child adapts their behavior with new and useful strategies, thus furthering development
Active Engagement	The therapist’s artful creation of challenging, yet playful, sensory-rich environments entice the child to participate actively in play; the methods of play incorporate new and advanced abilities that increase the child’s repertoire of skills and processing.
Child Directed	The therapist constantly observes the child’s behavior and reads their behavioral cues, thus following the child’s lead or suggestions. The therapist uses the child’s cues to create enticing, sensory-rich activities.

tive sensations. The therapeutic environment is designed to tap into the child’s inner drive to play. The therapist uses keen observation skills to observe and interpret the child’s behaviors and interests and then creates a playful environment in which the child actively pursues achievable challenges [Bundy et al., 2002; Kimball, 1993; Smith–Roley and Spitzer, 2001; Schaaf and Smith–Roley, in press]. For example, occupational therapy using a sensory integrative approach for a child with developmental dyspraxia and poor body awareness might include facilitating the child climbing across a low platform to access a large area filled with colorful balls (ball pit), then completing an unfamiliar obstacle course that consists of climbing up a rope ladder attached to the wall, jumping into large pillows that have a variety of textures, and then pulling him/herself out of the pillows using a rope attached to the opposite wall. Thus, the child is guided through challenging and fun activities designed to stimulate and integrate sensory systems, challenge their motor systems, and facilitate integration of sensory, motor, cognitive, and perceptual skills.

Astute observation of the child’s ability to process and utilize sensory information during these playful activities is a key skill of therapists trained in the sensory integrative approach and a feature that distinguishes this approach from others. The therapist observes the child’s responses during the activity and increases or decreases the sensory and motor demands to create a challenging and therapeutic environment. In keeping with the theory, goals and progress are recorded in the observable changes in the child’s ability to participate in sensory-based activities, regulate arousal level, improvement in sensory motor skills, and

improvement in ability to participate independently in daily life activities. In addition to direct intervention with the child, the therapist interacts and collaborates with parents, teachers, and others who are involved with the child to 1) help them understand the child’s behavior from a sensory perspective, 2) adapt the environment to the needs of the child, 3) create needed sensory and motor experiences throughout their day in their natural environments, and 4) assure that therapy is helping the child become more functional in their daily life activities.

USEFUL POPULATIONS FOR THE SI APPROACH

Although the original theory was developed for children with learning disabilities, Ayres recognized the utility of the theory for other clinical populations. For example, Ayres and Tickle [1980] applied the theory to children with autism and noted that it helped decrease tactile and other sensitivities to stimuli that interfere with their ability to play, learn, and interact. Since that time, sensory integrative principles have also been applied to various populations, including infants born at risk and/or with regulatory disorders, children with autistic spectrum disorders, fragile X syndrome, attention deficit disorder (ADHD) [Ognibene, 2002], and children from environmentally deprived situations [Cermack, 2001].

A high frequency (80–90%) of sensory processing problems are reported in children with autism spectrum disorders [Ornitz; 1974; O’Neill and Jones, 1997; Kientz and Dunn, 1997; Huebner, 2001]. Poor sensory processing may contribute to the maladaptive behavioral profile of these children and impact on their ability to participate in social,

school, and home activities [Anzalone and Williamson, 2000; DeGangi, 2000; Schaaf et al., 2002]. Children with autism often demonstrate extreme aversion to or excessive seeking of sensory stimuli, avoidance of noisy situations, unusual preoccupation with smells or visual stimuli, or fearfulness of typical activities that involve touch, sounds, and movement [Kientz and Dunn, 1997; Huebner, 2001; Mailloux, 2001; Mailloux and Smith Roley, 2001]. Whether these aberrant behaviors arise as a mechanism to maintain arousal [Ayres, 1979; Ornitz, 1989], to limit distraction to other stimuli, or because the children are self-absorbed by sensation, the net effect is limitation of the child's ability to participate in school, home, and play activities with their family and peers. Self-reports from individuals on the autistic spectrum confirm these findings and are powerful in terms of describing the impact of sensory dysfunction on participation in daily life activities [Williams, 1992, 1994; Grandin, 1995; O'Neill and Jones, 1997]. These descriptions portray how over- or underresponsiveness to the typical sensations of daily life pervade behavior and limit the individual's ability to participate fully in society. For example, Grandin [1995], a high-functioning individual diagnosed with autism, articulates how her unusual processing of auditory, visual, and tactile information makes it difficult for her process more than one stimulus simultaneously, which impacts her ability to socially interact. As a result, she does not enjoy or participate in many typical activities with others.

UPDATES IN THEORY AND PRACTICE

Since its conception in the late 1960s, Ayres' original theoretical principles have been extended, updated, and advanced based on advancements in science and clinical practice. One recent development is the proposed grouping of SI into three classic patterns, each of which consist of several subtypes: Sensory Modulation Disorder, Sensory Discrimination Disorder, and Sensory-based Motor Disorders as demonstrated in Figure 1. The authors suggest that delineating these subtypes is crucial so that homogenous groups may be identified to guide intervention and research related to describing the phenotypes of sensory processing disorder and evaluating the effectiveness of intervention with this population.

The pattern of poor sensory modulation has been most frequently discussed in the literature. Defined as "a

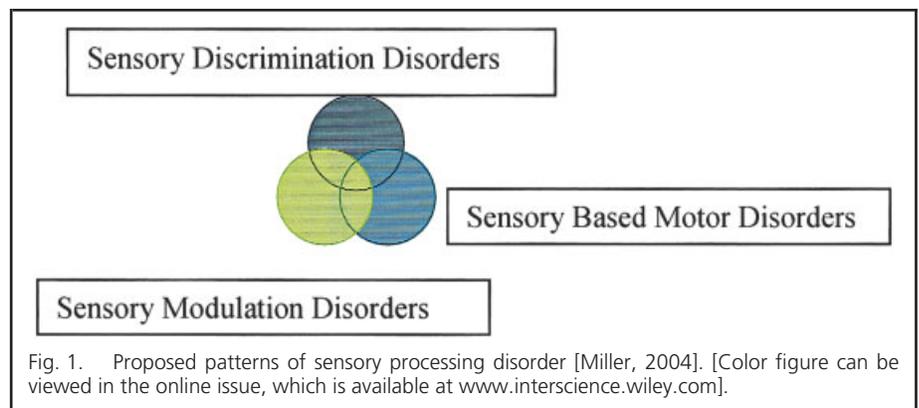


Fig. 1. Proposed patterns of sensory processing disorder [Miller, 2004]. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com].

problem in the capacity to regulate . . . response to sensory input in a graded . . . manner. . . [that] disrupts ability to achieve and maintain an optimal range of performance necessary to adapt to challenges in life" [Miller and Lane, 2000], children with poor sensory modulation are reported to over or underrespond to normal levels of stimuli in their environment. Efforts at screening for poor sensory modulation have been made easier by the Sensory Profile [Dunn, 1999a, 1999b], The Infant Toddler Sensory Profile [Dunn, 2002], and the Adult Sensory Profile [Brown and Dunn, 2002]. These tools are parent/self questionnaires that describe responses to sensation during daily life activities.

In an effort to identify the underlying mechanisms of poor sensory modulation, Miller, et al. [2005] completed a series of studies examining autonomic nervous system functioning in children with poor sensory modulation. They have shown that children with severe hyperresponsivity and Fragile X syndrome have markers of sympathetic dysfunction evidenced by electrodermal activity with significantly increased amplitudes, more frequent responses, and less habituation than matched controls [Miller et al., 1999]. They also studied children with poor sensory modulation and no other developmental diagnosis identified clinically. These children also showed significant markers of sympathetic dysfunction [McIntosh et al., 1999]. In addition to sympathetic markers of sensory dysfunction, parasympathetic markers have been evaluated [Schaaf et al., 2003], suggesting that the functioning of the sympathetic and parasympathetic systems should be considered together when trying to understand the contribution of the autonomic nervous system to poor sensory modulation. Studies of children diagnosed with attention deficit disorders showed a range of responses in regard to sensory processing

with about two-thirds of the sample showing symptoms of poor sensory processing [Mangeot et al., 2001]. Approximately 40% of the sample of children with poor sensory modulation also had symptoms of attentional deficits [Ahn et al., 2004]. This population had different sympathetic markers of sensory reactivity [Roley, et al., 2005] and decreased response inhibition in the presence of normal sensory habituation [Ognibene, 2002].

The most recent contribution to practice and to advance research is the efforts of the Sensory Processing Disorders Scientific Workgroup [SPD, 2004], a multidisciplinary group of established leaders in developmental psychobiology research. The group is studying diverse aspects of atypical sensory processing, including central metabolic differences using proton magnetic spectroscopy, physiological correlates of early perceptual processing, sensory gating evoked potential (P50) discrimination, and genetic factors that relate to the etiology, for example. Additional research questions posed by this workgroup relate to differences in dopamine D2 receptor binding availability, presynaptic dopamine synthesis, and serotonin receptor availability in SMD, and pharmacological agents for treatment of children with poor sensory processing.

PREVALENCE

Although clinicians and educators have speculated that the prevalence of children affected by poor sensory modulation is high, the true numbers have only recently been appreciated. Miller and colleagues conducted a survey to estimate rates of sensory processing disorders in incoming kindergartners from one suburban U.S. public school district [Ahn et al., 2004]. The Short Sensory Profile, a carefully researched version [McIntosh et al., 1999] of the Sensory Profile parent-report screening tool, was utilized. A conservative estimate of prevalence was

made, assuming that all nonrespondents failed to meet positive criteria for SMD. Approximately 5% of the kindergarten enrollment met screening criteria for sensory processing disorders.

EVIDENCE SUPPORTING THE THEORY, PRINCIPLES, AND PRACTICE OF SI

General knowledge and empirical research are needed to validate a new area of clinical investigation. To develop consensus, a state of “equipose” (Kuhn Structure of Scientific Revolution) must be reached. Equipose is a state of agreement within the community for whom the issue has meaning, such as families with children affected, researchers, clinicians, and scholars. To achieve this state, empirical research must be conducted and findings must be generalized to the people who are stakeholders. The researchers and stakeholders build a community based on a consensus of beliefs. An excellent method to generate confidence in a new methodology is by replication of treatment effects.

Currently, efforts to facilitate consensus regarding the merits of OT using a sensory integrative approach are underway. One reason for the lag in this area is that the science of OT is relatively new compared to fields such as psychology and medicine with longer traditions of research and trained scientists. OT is historically a field of service provision, so efforts have mainly focused on practice issues. Many case studies detailing the use and effectiveness of OT using a sensory integrative approach have been published in the peer-reviewed literature with examples of strategies that might have utility for clinicians and for generating hypotheses [Schaaf, et al., 1987; Case-Smith and Bryan, 1999; Linderman and Stewart, 1999; Baranek, 2002; Mulligan, 2003a, 2003b]. As the number of occupational therapists with doctoral level training increases, the availability of research scholars who can implement independent research grows, and the funding for this type of research is expanded, new research to facilitate consensus will expand.

The best route to establishing a consensus is convergence of results from multiple studies and replication [Ziman, 1968]. Public acceptance of the principles of SI also encourages empirical research. For OT/SI this has been supported by several factors. First, individuals affected by autism began to verbalize the impact of poor sensory processing on behavior and function [Grandin, 1986; Williams, 1992, 1994;

Grandin, 1995]. These verbal individuals provided new insight into how sensory over- or underresponsiveness limits their own ability to function effectively in their various roles and daily life activities. They report the importance of intervention strategies to address their own atypical sensory processing. Second, the popular best seller, *The Out of Sync Child* [Kranowitz, 1998], rekindled interest in OT using a sensory integration approach. Parents identified with the descriptions provided in the Kranowitz book and began to seek treatment approaches that addressed sensory issues. They began pushing from the consumer side for services based on a desire to help their child rather than waiting for analysis of scientific evidence.

Although public awareness and acceptance of OT using a sensory integrative approach increased, a tension between the push for services and empirical science supporting this approach remained. Until empirical consensus is reached about the effectiveness of this approach, the practice will not be widely accepted by the broader scientific community, and the consensus will be limited to the therapeutic community. Fortunately, the efforts described in this article are actively working to close the gap between practice and research.

It is interesting to note that, although controversy regarding the effectiveness of OT using a sensory integration approach exists, over 80 studies have been conducted that measure some aspect of the effectiveness of this approach for intervention. About half of the studies demonstrate some type of treatment effectiveness. Two metaanalyses [Ottensbacher, 1982; Vargas and Camilli, 1999] and four research reports [Palatjko, et al. 1992; Arendt et al., 1988; Hoehn and Baumeister, 1994] have been published summarizing these outcome studies. Some of the syntheses concluded that the approach is effective and other syntheses suggest the intervention was equally effective as other approaches.

At this point in time, interpretation of the findings of these 80 studies is difficult due to three methodological limitations. The first key challenge for OT researchers is defining the independent variable (the treatment) in a manner that is replicable. As this intervention approach is individualized (often compared to the way psychotherapy is individualized), standardization of treatment has been a challenge to outcome research. Recent progress to define the intervention has been made by a multisite research group funded by an NIH R21

planning grant. This group completed a thorough review of existing treatment resources and developed a treatment protocol and a “Fidelity to Treatment Measure” to evaluate whether the therapy that is administered is true to the principles established in the literature for the treatment. The Fidelity Scale evaluates constructs related to the intervention provided, details the training of the persons administering the intervention, and specifies the environment in which the treatment is conducted.

A second key challenge to interpreting existing research that evaluates the effectiveness of OT using a sensory integrative approach is 1) dependent measures used in previous research were not related to the purpose of the intervention; 2) researchers did not utilize a theoretical base to explain the how the putative mechanisms of the treatment are measured by the specific outcomes utilized; and 3) multiple outcomes were utilized instead of specifically targeted outcomes to the surmised mechanisms of treatment.

In addition, research has been conducted on “sensory integration” as an isolated modality rather than embedding it in the context of a full OT program [Polatjko et al., 1992] as was originally intended. Ayres always used an occupational frame of reference in providing intervention [Ayres, 1972, 1979, 1989]. This means that the goals of therapy are always functional abilities and routines, include “occupations” of early childhood such as sleeping, eating, dressing, playing, interacting with others, learning, and so on, and embody key concepts such as active participation and the just right challenge. Thus, these studies, while interesting, are not informing the public about OT using a sensory integrative approach. Next, few studies establish a theoretical basis for their hypotheses, citing instead the question, “Does sensory integrative treatment work?,” which is a simplistic and atheoretical question. Finally, in existing research many studies use multiple outcome measures with no good explanation of how the outcomes relate to the suspected effects of treatment and utilize [Densem et al., 1989] a “fishing expedition” approach hoping to find *something* that might be statistically significant. The statistical result of this type of study is that the strength of the treatment is likely to be reduced because there is no hypothesis about the relation between the treatment and outcomes. Researchers run the risk of nonsignificant and uninterpretable results [Ottensbacher,

1991], hence some of the findings of nonsignificance are difficult to interpret.

The multisite R21 research team working on the challenge of treatment replication is also working on a systematic way to apply goal attainment scaling (GAS) as a primary outcome measure for effectiveness studies. GAS provides a means to establish intervention goals that are specifically relevant to individuals and their families and that allow comparison of achievement across diverse desired functional outcomes. GAS in combination with physiological outcome measures will provide a method for measuring effectiveness that will increase the integrity, strength, and replicability of future effectiveness studies.

The third key challenge relates to the homogeneity of the samples studied. A limitation of previous studies was the difficulty in defining a homogenous group. The heterogeneity of samples in previous research increased within-group variability and reduced the probability of finding significant group differences. Now with the publication of the Sensory Profiles and the physiological paradigm, the Sensory Challenge Protocol [Miller et al., 1999], which suggests electrodermal activity criteria for inclusion in specific sensory processing subtypes, future studies can define their samples in a manner that allows replication across sites.

The limitations in previous studies result in the absence of consensus in the field regarding the effectiveness of SI interventions. The field is using lessons learned to improve future studies, moving the research forward. Careful examination of the approximately 80 previous studies reveals that important contributions to the study of sensory processing disorder have been made. Given the current level of research, diverse findings are not surprising. This inconsistency is predictable, given the variation in sample characteristics, intervention methods and duration, and outcomes measured. The knowledge base in this field is in its infancy and substantial work is needed before enough rigorous empirical data are available to proffer valid conclusions about the effectiveness of this intervention approach.

In conclusion, significant progress has been made in defining homogenous subgroups for analysis, in describing a replicable treatment, and in choosing valid outcome measures. However, gaps exist in knowledge related to sensory processing disorder and the effectiveness of occupational therapy in ameliorating this condition. Hence, in the field of occupational therapy, we have a clear and

exciting challenge to action. The field offers tremendous promise. Studies are underway to elucidate the underlying mechanisms of the impairment, to define the phenotypic characteristics of the disorder, to discriminate the disorder from other developmental disorders (e.g., ADHD and autism), and to evaluate the effectiveness of OT services in remediating the dysfunction. New research with stronger empirical standards is forthcoming. We are on the cusp of an explosion of knowledge in this area providing rigorous scientific data to move the field forward. Scientists and practitioners alike must promote research that leads to better diagnoses and effective interventions, improving the lives of children and their families. ■

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Occupational Therapy Using a Sensory Integrative Approach: A Case Study of Effectiveness

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KEY WORDS

- effectiveness
- occupational therapy
- pediatric
- sensory integration
- sensory processing

OBJECTIVE. This article presents a case report of a child with poor sensory processing and describes the disorder's impact on the child's occupational behavior and the changes in occupational performance during 10 months of occupational therapy using a sensory integrative approach (OT-SI).

METHOD. Retrospective chart review of assessment data and analysis of parent interview data are reviewed. Progress toward goals and objectives is measured using goal attainment scaling. Themes from parent interview regarding past and present occupational challenges are presented.

RESULTS. Notable improvements in occupational performance are noted on goal attainment scales, and these are consistent with improvements in behavior. Parent interview data indicate noteworthy progress in the child's ability to participate in home, school, and family activities.

CONCLUSION. This case report demonstrates a model for OT-SI. The findings support the theoretical underpinnings of sensory integration theory: that improvement in the ability to process and integrate sensory input will influence adaptive behavior and occupational performance. Although these findings cannot be generalized, they provide preliminary evidence supporting the theory and the effectiveness of this approach.

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Children with poor sensory processing often have difficulty regulating their responses to sensation. Lane, Miller, and Hanft (2000) described this as sensory modulation disorder, an inability to “regulate and organize the degree, intensity, and nature of response to sensory input in a graded and adaptive manner” (p. 1). Occupational therapy intervention for this population uses principles from sensory integration theory and focuses on engagement in child-directed, sensory-rich experiences that are individually designed to address each child's specific sensory needs (Ayles, 1979). The therapist artfully engineers and adjusts the sensory qualities of the environment, promoting self-direction and play while facilitating adaptive responses in motor, affective, social, language, and cognitive areas; creating the “just-right challenge”; and tapping the child's inner drive (Ayles, 1972; Schaaf & Smith Roley, 2006). “The goal of intervention is to improve the child's ability to process and integrate sensory information as a basis for enhanced independence and participation in daily life activities, play (including social participation) and school tasks” (Schaaf & Miller, 2005, p. 2).

The ability to modulate sensory information provides a foundation for meaningful and purposeful participation in a full range of daily occupations, and therefore, people with poor sensory modulation often have problems successfully meeting the challenges of everyday life (Lane et al., 2000). They demonstrate extreme hyporesponsivity or hyperresponsivity to typical levels of sensory input and exhibit

unusual patterns of sensation seeking or avoiding that impede full participation in everyday activities such as dressing, playing, mealtime, bath time, and social interaction with others (Dunn, 1997). Frequently, extreme emotional states such as anxiety, depression, anger, and hostility also are present (Schaaf & Smith Roley, 2006). Parents report that poor social participation, self-regulation, and perceived competence are key difficulties experienced by their children (Cohn, Miller, & Tickle-Degnen, 2000).

Although occupational therapy using a sensory integrative approach (OT-SI) is widely used for children with poor sensory modulation, evidence supporting its value and effectiveness is controversial and inconclusive. Efficacy studies have shown varying results (see Miller [2003] and Mulligan [2003] for reviews) partly due to the heterogeneity of the population, lack of strict adherence to the principles of sensory integration theory and treatment, and use of outcome measures that are not "occupation" based. Given these issues, one strategy for evaluating the effectiveness of intervention for this population is the case study approach. This approach allows the researcher to provide an in-depth analysis of a person's intervention outcomes and changes in behavior as a consequence of intervention and allows the use of multiple methods of data collection to explain the complexity of the case (DePoy & Gitlin, 1998). Although the case study approach does not allow generalization of findings, it informs clinical practice by explicating clinical problems and useful solutions.

Methods

A descriptive case study design was used to evaluate the effectiveness of OT-SI. A history and occupational profile (Schaaf & Smith Roley, 2006) revealed that many of the participant child's presenting problems could be related to sensory avoidance and hypersensitivity to sensation. To further assess this hypothesis, the Sensory Profile (Dunn, 1999), an interview with the parent, a review of previous evaluation reports, and systematic observation of behaviors were performed. Based on assessment data, specific goals were developed and reviewed with the child's mother to assure that the goals were meeting identified and appropriate areas of concern. Documentation of progress toward goals was collected and charted weekly. A parent interview was conducted during the final month of intervention to obtain input about the child's past and present occupational concerns and the success of the OT-SI program in meeting his needs.

Participant

J was a 4-year-old male who lived with his parents and older brother in a suburban area. He was born after a full-term

pregnancy with no birth or early infancy complications. J's mother described him as a hesitant child who stayed close and rarely wandered or got into things. At about 2 years of age, when J's language lagged, his parents contacted the local early intervention agency and were provided with speech and language therapy, occupational therapy, and educational support services. The focus of intervention was a developmental approach that facilitated skill development through the use of developmentally appropriate activities. In reflecting on J's development, J's mother noted,

The summer that he turned 2, he stood out . . . compared to other kids. He was running around saying the alphabet, that's all he would do. He was completely obsessed with numbers and letters. He could say his ABCs forward and backward, but he couldn't say "Mom, juice." He had a few words that referred to everything. I started to notice . . . lots of issues with him, lots of texture aversions. If we were walking in the grass, he would not take two steps forward. He would put his feet in the ground and not move until someone picked him up . . . because he did not like the feel of that. And it just broke our hearts to see him not find joy but fear and major blocks with things that should be normal, everyday, fun childhood play things. (J's mother, personal communication, July 25, 2002)

After 1 year of early intervention, a comprehensive reevaluation found that, although some improvements were noted, J still had substantial needs in his expressive language skills and his overall social, emotional, behavioral, motor, and sensory development. J was still hesitant to participate in new activities and avoided sensory activities, which was affecting his ability to participate in social contexts or to play independently. In addition, J's mother now noticed oral sensory sensitivities as well as movement and auditory sensitivity:

He never explored anything orally. He would never take a pacifier, he absolutely refused to take a bottle. . . . He drooled much longer than a child should . . . and he had major texture aversions to foods. He had such a limited diet, it was scary. I remembered slicing pears and putting them on a plate, and [him] physically start shaking from the texture, and flinging it [across the room]. . . . He never sought out movement. . . . He would not go up or down our stairs. As a parent, it was wonderful: I didn't need any gates, he was scared to death, and he wouldn't explore any of that. Playground was really tough for him. He would circle around and never really climb on anything. Kids would ask him to, he would say no, shut his eyes, and walk away. That was the hardest for me, seeing him struggle so much with something he should be enjoying. [Socially] he never really interacted with a lot of kids. He was so overwhelmed with anyone he didn't know well. He never was the kind of kid that would flip out or get angry; instead, he would shut

down and he would block out noises and sounds and stimuli that bothered him. (J's mother, personal communication, July 25, 2002)

J's mother decided to seek additional occupational therapy services, specifically OT-SI. The primary therapist was certified in the Sensory Integrative Process by the University of Southern California/Western Psychological Services and had 20 years of experience using the sensory integrative frame of reference as part of her occupational therapy practice.

Measures

The Sensory Profile (Dunn, 1999) was used to assess J's behaviors and their potential sensory basis. The Sensory Profile is a measure of children's responses to sensory events in daily life that provides data about how patterns in sensory development might be contributing to, or creating barriers to, performance in daily life (Dunn, 1999). The Sensory Profile's content validity is reported at 63%, and construct validity is rated as moderate (see Dunn, 1999, for more details). J scored in the definite difference range on 5 of the 14 category sections and 3 out of 8 factors, and in the probable difference range on 3 of the categories and 2 of the factors as detailed in Table 1. J was not administered the Sensory Integration and Praxis Tests because he was unable to manage the complex directions associated with this test at this time.

Table 1. Sensory Profile Test Scores for J

Category/Section	Difference Rating
Sensory Processing	
Auditory Processing	Probable
Visual Processing	Probable
Vestibular Processing	Typical
Touch Processing	Definite
Multisensory	Probable
Oral Sensory	Typical
Modulation Processing	
Sensory Related to Endurance/Tone	Definite
Modulation to Body Position/Movement	Definite
Modulation of Movement/Activity Level	Typical
Modulation of Sensory Input/Emotional	Definite
Modulation of Visual Input	Typical
Behavioral/Emotional Responses	
Emotional/Social Responses	Definite
Behavioral Outcomes of Sensory Processing	Probable
Thresholds of Responses	Typical
Factors	
Sensory Seeking	Typical
Emotionally Reactive	Definite
Low Endurance/Tone	Definite
Oral Sensory Sensitivity	Typical
Inattention/Distractibility	Typical
Poor Registration	Probable
Sensory Sensitivity	Definite
Sedentary	Probable

Goals for therapy were developed in collaboration with J's mother and focused on improving sensory processing as a basis for enhanced ability to participate in everyday activities. In keeping with the theory of sensory integration and the practice guidelines for occupational therapy (American Occupational Therapy Association, 2002), goals were based on assessment findings and focused on occupation-based outcomes *and* the underlying sensory components that had an impact on these (Mailloux, 2006). J's goals are detailed in Figure 1.

Goal attainment scaling was used to document, quantify, and compare progress on each goal. The system for developing the goal attainment scale followed the recommendations in the literature (Kiresuk, Smith, & Cardillo, 1994; Mailloux et al., 2007; Ottenbacher & Cusick, 1990). The rating for each goal for every session was determined by reviewing weekly progress notes to determine the scaled rank.

Assessment Findings

The occupational therapy assessment of J's strengths and needs indicated that J demonstrated notable deficits in sensory processing that were affecting his ability to participate optimally in social, play, and home activities. Specifically, he demonstrated hyperresponsivity to tactile, vestibular, oral-sensory, and auditory stimuli; a limited food repertoire; exaggerated emotional, behavioral, and fear responses to sensation and everyday activities; and expressive language delays. His occupational therapy report summarized:

J is a shy and quiet 4¹/₂-year-old child referred for an occupational therapy evaluation to assess sensory integrative and praxis abilities and needs, and to determine if delays in these areas may be affecting his participation in age-appropriate activities. Specifically, his mother notes that he has excessive fear reactions to typical movement/play activities (such as playground equipment), limited strategies for play and interaction with others, a significantly limited food repertoire, and delayed communication skills. He has a supportive family, enjoys ball skills, and demonstrates emerging language and communication skills. J is interested in play, but is very hesitant and fearful to engage in many gross motor play activities such as climbing and jumping. He primarily uses vision to explore his environment and is a passive, observant child. When coaxed to play, however, and provided with play ideas, J engages hesitantly. Assessment findings indicate that poor sensory processing contributes to described difficulties. Specifically, he demonstrates sensitivity and fear of movement activities, and excessive sensitivity to auditory stimuli and tactile sensations in his mouth and on his body. In addition, he demonstrates a moderate dyspraxia in that he has difficulty creating ideas and schemes for play and movement activities. (R. Schaaf, personal communication, July 28, 2002)

<p>1. J will demonstrate an increase in sensory and motor skills as a basis for independent participation in age-appropriate home, school, and community activities. <i>Measurement: 80% of the time as observed by the therapist and reported by parents.</i></p>				
-1 J requires assistance to complete a 1-step activity	0 J will request and perform a simple motor activity	1 J will independently request and complete a 2-step sequence	2 J will independently request and complete a 3- to 4-step sequence	3 J will independently request and complete a 4- to 6-step sequence during session
<p>2. J will participate in vestibular activities without fear reactivity as a basis for age-appropriate play with peers. <i>Measurement: 80% of the time as observed by the therapist and reported by parents.</i></p>				
-1 J will participate in 5 min of vestibular activities during OT session	0 J will participate in 10 min of vestibular activities with support from parent or therapist during OT session	1 J will participate in 15 min of vestibular activities with support from parent or therapist during OT session	2 J will participate in 20 min of vestibular activities with minimal support from parent or therapist	3 J will participate in age-appropriate activities that have a vestibular component (swings, playground activities) at home/community settings
<p>3. J will participate in a variety of oral sensory activities as a basis for expanded food repertoire and increased participation in mealtime and snack time. <i>Measurement: 80% of the time as observed by the therapist and reported by parents.</i></p>				
-1 J will refuse to eat non-preferred food during oral-motor session	0 J will take 1 bite of non-preferred food and participate in oral motor play for 5 min during session	1 J will participate in oral-motor play (whistles, bubbles) for 10 min with peer	2 J will choose non-preferred food initially during snack session and will participate in oral-motor play for 15 min	3 J will tolerate preferred/non-preferred foods interchangeably throughout snack session and participate in oral-motor play independently
<p>4. J will demonstrate improved social development as a basis for participation in play with peers. <i>Measurement: 80% of the time as observed by the therapist and reported by parents.</i></p>				
-1 J will initiate social interaction with peer with direction and prompting	0 J will initiate 1 social interaction with peer during OT session	1 J will tolerate 15 min of social interaction with peer	2 J will have a 10-min conversation with peer during OT session	3 J will initiate 3 or 4 social situations with peer to promote social awareness and interaction
<p>5. J will demonstrate age-appropriate fine-motor skills as a basis for participation in school activities. <i>Measurement: 80% of the time as observed by the therapist and reported by parents.</i></p> <p>Cutting/Hand Manipulation/Grip Strength</p>				
-1 J requires moderate physical assistance to snip paper and to maintain proper scissor positioning	0 J requires minimal physical assistance to snip paper and to maintain proper scissor positioning	1 J requires moderate verbal cues to snip paper in proper direction and to maintain proper scissor positioning	2 J requires minimal verbal cues to snip paper in proper direction and to maintain proper scissor positioning	3 J can independently cut across paper and maintain proper scissor positioning throughout
<p>Hand Strength/Visual Motor Coordination</p>				
-1 J requires maximum assistance in throwing and catching a ball from 10-feet distance	0 J requires moderate assistance in throwing and catching a ball from 10-feet distance	1 J requires minimal assistance in throwing and catching a ball from 10-feet distance	2 J requires minimal assistance in throwing and catching a ball from 15-20-feet distance	3 J can throw and catch a ball independently from 15-20-feet distance

Note. OT = occupational therapy. Each of J's five main goals were ranked and scaled according to the following scale: -1 = J has regressed from his previous treatment session in this particular goal; 0 = current level of functioning at start of treatment; 1 = reflects incremental progress in the specified goal; 2 = reflects significant progress in the specified goal; 3 = J has attained this goal.

Figure 1. Goals and goal attainment scale for J.

Based on the assessment results, direct OT-SI was recommended once per week with frequent consultation and collaboration with J's mother (weekly) and J's preschool teacher (monthly). Direct, individual therapy was aimed at remediation of the underlying sensory hypersensitivities. Consultation with the teacher was accomplished through the use of phone conversation and a notebook that J's mother relayed to the school weekly. Therapy was provided in an OT-SI clinic consistent with the criteria outlined by Parham and colleagues. (2007), Schaaf and Smith Roley (2006), and Slavik and Chew (1990). A typical treatment session is outlined in Table 2.

Results

Goal Attainment Scales

Visual inspection of J's goal attainment scales (using Excel line graphs) shows that J attained his target level in each of the 5 occupational therapy goals as depicted in Figure 2. To summarize, J (a) demonstrated improvements in motor planning and participation in age-appropriate

activities, (b) decreased fear reactivity to movement (vestibular) activities and participation in age-appropriate playground equipment, (c) decreased oral-sensory sensitivity and expanded his repertoire of food and participation with family and peers at mealtime, (d) improved social development and began to initiate social play with peers, and (e) improved manual exploration and participation in age-appropriate fine and visual-motor and play activities.

J's improvements in his ability to tolerate and process sensory input were striking and apparent in home, community, and clinic environments. His decrease in fear of movement and tactile stimuli set the stage for participation in age-appropriate play, thus enhancing socialization opportunities. During his occupational therapy sessions, he progressed from unwillingness to participate in climbing and movement activities to playfully enjoying such activities. J was observed joyfully playing on swings, climbing up, and participating in a variety of sensorimotor activities. Similarly, he tolerated oral-sensory stimuli and ate a variety of foods, thus enabling him to participate more successfully in mealtime activities.

Table 2. A Typical OT-SI Treatment Session for J

Activity	Purpose	Example	Comments
Warm-up	To ensure that the child is comfortable and relaxed for play	Greeting and playful interactions: "Hi, J, did you come to play with (X) today?" "What would you like to play with today?" ¹	Favorite game is tossing bean bags at a large stuffed bear in attempt to knock it over.
Active sensory motor play with a focus on multisensory input	To decrease sensory sensitivities and increase praxis	Swinging on space bag and crashing into large pillows and bolsters. Space bag is set low to ground to offset any fear that J might have and to encourage independence during this activity.	Therapist sets up environment with J's needs in mind and then observes child, following the child's cues, to select activity. ²
Active sensory motor play with a focus on praxis	To decrease sensory sensitivities, improve awareness of body, and increase praxis	Therapist helps J create a "bridge" (two triangular climbing devices with a flat bolster suspended between them). J climbs up ladder (with assistance), climbs onto bolster, and then jumps into large "crash pad" (pillows). ³	Therapist vigilantly observes J's reactions and actions, encouraging J as needed but allowing for as much self-direction and independence as possible. ⁴
Snack with a focus on socialization	To decrease oral sensitivities, expand food repertoire, and enhance socialization	J brings a snack to share with another child. J sets up snack, invites other child, and participates in snack.	Mother packs food and beverage that J enjoys in addition to one or two foods that J is not familiar with or usually avoids.

Note. OT-SI = occupational therapy with a sensory integration approach. Activities are upgraded and downgraded to meet the child's needs and to ensure success. Therapy is contextualized in sensory-rich play and taps into the child's inner drive for competence (Ayres, 1979). The therapist artfully and skillfully creates enticing, achievable challenges for the child to promote the ability to process and integrate sensory information and observes adaptive responses to these challenges.

¹If no response: "I have your favorite game ready. Do you want to play?"

²Upgrade—Add tactile and motor planning component (count to 3 and "crash" into pillows).

³If child is not willing to climb up to bridge, therapist downgrades by lowering bridge.

⁴Therapist uses playful language (singing) or pretend play (climbing into spaceship).

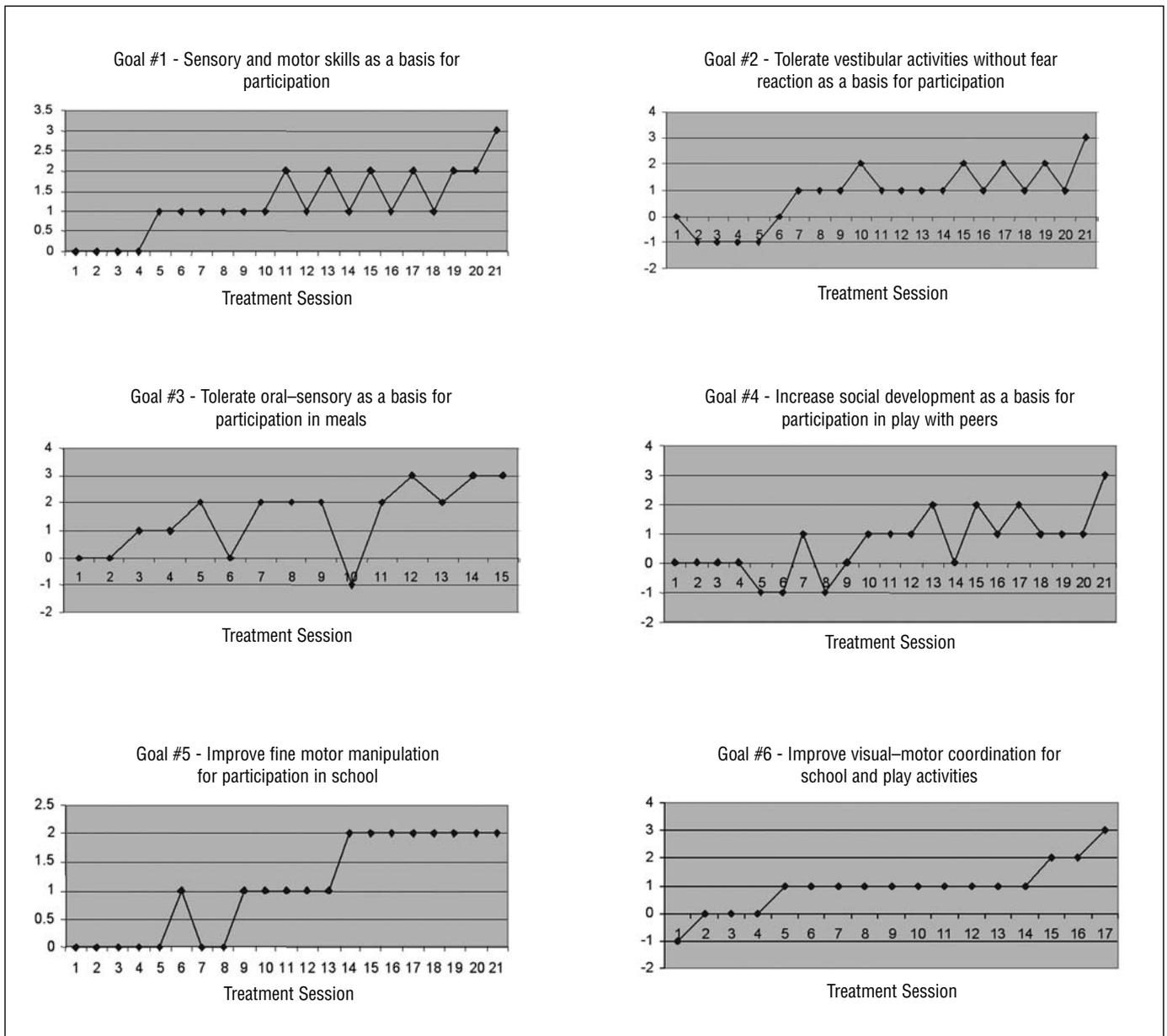


Figure 2. Goals and goal attainment scales. J demonstrated visible improvements in all goals.

Parent Interview

The parent interview conducted during the final month of occupational therapy services revealed substantial improvements in J's occupational performance and participation. J's mother described how his improvements in sensory processing allowed him to participate in age-appropriate activities more successfully, complete self-care activities independently, socially interact with family and peers more effectively, and perform more successfully in school. She also noted the positive impact these improvements had on their family routines:

He is [now] able to withstand different textures, tactile/touch things that he wasn't able to before. We are able to go to the beach, and J will play and walk in the sand. He [is doing things now] that originally he said he

would never do: go down a slide, climb, jump off something. I get such gratification out of watching him play on the playground . . . he's a totally different kid. . . . [Before therapy] he was scared of sound. That was probably one of the things that improved the fastest for him. . . . [He] had some pretty noticeable severe sensory issues that I was not educated about before he started his [OT-SI], and the work they have done with him has just been phenomenal. (J's mother, personal communication, July 25, 2002)

Although the Sensory Profile is not designed as a posttest assessment, it was completed after 10 months of intervention as a reassessment tool to determine any further areas of need for J. At this time, J showed typical performance in all but 3 subtests where he showed only a probable difference, suggesting that poor sensory processing was no longer a factor for J.

Discussion

This article presents a case study report of a child with poor sensory modulation and occupational performance deficits, and details improvements in occupational performance during 10 months of OT-SI. Most important, this case provides a model of occupational therapy intervention rooted in theory-based clinical reasoning, exemplifying the use of sensory integration theory to address the underlying issues affecting occupational performance and the tenets of occupational therapy practice to guide the assessment, intervention, and outcome measurement. Thus, this report illustrates best practice and a contemporary model for clinical research.

Second, this case contributes to the evidence for using a sensory integrative approach within occupational therapy, demonstrating, as Ayres (1979) intended, the interrelationships among sensory processing, behavior, and occupational performance. Ayres clearly articulated in her theory of sensory integration that inadequate sensory integration affects behavior and development. She stated, "If the brain does a poor job of integrating sensations, this will interfere with many things in life. There will be more effort and difficulty, and less success and satisfaction" (Ayres, 1979, p. 7). Clearly, J's behavior, development, and participation were adversely affected by poor sensory processing, and thus the theory of sensory integration provides the basis for an intervention program.

Last, this case exemplifies a systematic method of data collection and analysis that may be useful in the clinical setting for evaluating outcomes of occupational therapy. We occupational therapists have a professional responsibility to monitor and evaluate our effectiveness. Pressure from outside sources—including funding agencies, administrators, and parents—demand that we demonstrate whether occupational therapy is helping children participate more successfully in their various life environments (e.g., school, home, community), and this case provides a model for doing so.

Limitations

Although this case provides information that can be useful for clinicians working with children who have poor sensory processing, because it is a case report the results cannot be generalized to the population of children with poor sensory processing. Additional studies are needed to validate the findings. Nevertheless, as suggested by DePoy and Gitlin (1998), this limitation is somewhat offset by the ability of this type of research to provide a guide for clinical practice and to validate theory. A second limitation is related to the validity and reliability of data collection methods. Assessment data relied mainly on parent report, history taking,

interview, and chart review and, as such, there is limited objective assessment data. The study would be strengthened by adding newly developed pretest and posttest measures of occupational performance *and* sensory behaviors such as the Miller Function and Participation Scale (Miller, 2006) (see King et al., in press, for additional suggestions). Finally, best practice includes not only direct intervention, but also thoughtful consideration of the environmental factors that influence behavior and learning, and consideration of the multiple environments in which children participate, and thus this study would be strengthened by greater collaboration with the classroom teacher and adaptations to the classroom environment to facilitate sensory processing and participation. ▲

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An Intervention for Sensory Difficulties in Children with Autism: A Randomized Trial

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Abstract This study evaluated a manualized intervention for sensory difficulties for children with autism, ages 4–8 years, using a randomized trial design. Diagnosis of autism was confirmed using gold standard measures. Results show that the children in the treatment group ($n = 17$) who received 30 sessions of the occupational therapy intervention scored significantly higher ($p = 0.003$, $d = 1.2$) on Goal Attainment Scales (primary outcome), and also scored significantly better on measures

of caregiver assistance in self-care ($p = 0.008$, $d = 0.9$) and socialization ($p = 0.04$, $d = 0.7$) than the Usual Care control group ($n = 15$). The study shows high rigor in its measurement of treatment fidelity and use of a manualized protocol, and provides support for the use of this intervention for children with autism. Findings are discussed in terms of their implications for practice and future research.

Keywords Autism spectrum disorders · Intervention · Sensory functions

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Introduction

Difficulty processing, integrating and responding to sensory stimuli has been described as a feature of autism spectrum disorders (ASD) since the disorder was first identified. Current estimates show that between 45 and 96 % of children with ASD demonstrate these sensory difficulties (Ben-Sasson et al. 2009; Lane et al. 2010) and sensory features (i.e.: hyper- or hypo reactivity to sensory input or unusual interest in the sensory aspects of the environment) are now included as one of four possible manifestations of 'Restricted, Repetitive Patterns of Behavior, Interests, or Activities' (American Psychiatric Association 2013). Families report that behaviors associated with difficulty processing and integrating sensory information create social isolation for them and their child, restrict participation in daily living activities (Schaaf et al. 2011) and impact social engagement (Hilton et al. 2007, 2010; Baker et al. 2008; Ashburner et al. 2008; Reynolds et al. 2011; Watson et al. 2011; Hochhauser and Engel-Yeger 2010). Consequently, interventions to address problems associated with difficulty processing sensory information, such as occupational therapy using sensory

integration (OT/SI), (Ayres 1972, 1979, 1989) are among the most often requested services by parents of children with ASD (Mandell et al. 2005; Green et al. 2006; Goin-Kochel et al. 2009). There is emerging evidence regarding positive outcomes of OT/SI for children with ASD (Pfeiffer et al. 2011; Fazlioglu and Baran 2008; and see Schaaf 2011 for a review), however, methodological limitations preclude definitive conclusions. Hence, there is the need for a rigorous study of OT/SI that includes a manualized protocol and measurement of treatment adherence (Case-Smith and Arbesman 2008; Watling et al. 2011). Fortunately, a validated measure of treatment fidelity that describes the key principles of the sensory integrative approach and provides guidelines for best practice is now available (Parham et al. 2011, 2007; May-Benson et al., in press). Importantly, this measure provides a means to evaluate the fidelity of OT/SI in a clinical trial while assuring internal and external validity; a standard that is followed in the current study.

A second advancement that enhances the testing of this intervention is data showing that Goal Attainment Scaling (GAS) is a useful outcome measure for studies of interventions for ASD (Ruble et al. 2012). GAS is used to measure functional and meaningful aspects of an individual's progress (Mailloux et al. 2007; Kiresuk et al. 1994). In autism, inherent heterogeneity often confounds findings, and thus, it is important to utilize outcome measures that are sensitive to individual outcomes. GAS has been shown to be a substantive and sensitive approach to evaluate progress on individualized goals in randomized controlled trials of psychosocial interventions for children with autism provided that specific quality indicators are present. These include that goals are independently rated, evaluated for equivalence between groups (comparability), scaled with equidistance, have measurable criteria, and clear, identifiable benchmarks (Ruble et al. 2012), recommendations that we followed in this study. A further strength of using GAS is that it provides a means to identify and measure outcomes that are parent-chosen and thus, meaningful to family. Given the increased emphasis on measurement of outcomes that are meaningful to the client or family (PCORI, <http://www.pcori.org>), the use of GAS provides a model for best practice.

Given the need for a rigorous randomized trial of OT/SI for individuals with ASD, the primary purpose of this study is to evaluate the efficacy of OT/SI following a manualized protocol on individual goal attainment (primary outcome) in comparison to usual care (UC). The secondary purpose was to evaluate the impact of this approach on the child's sensory behaviors, adaptive behaviors and functional skills.

Methods

Participants

Thirty-two children participated in this study. A convenience sample of eligible families was recruited from the children's hospital where the study took place and the surrounding community. Families were eligible to participate if their child: (1) was between the ages of 4.0 and 7.11 at the time of enrollment, (2) had a diagnosis of an autism spectrum disorder from a licensed psychologist based on the results of the Autism Diagnostic Interview-Revised (ADI-R) (Lord et al. 1994) and the Autism Diagnostic Observation Schedule (ADOS) (Lord et al. 1999), (3) had a non-verbal cognitive level of >65 (this IQ cut score is based on findings from an earlier study where we assessed the feasibility of conducting this intervention with children with ASD—Schaaf Benevides et al. 2012); (4) demonstrated difficulty processing and integrating sensory information as measured by the Sensory Profile (SP—Dunn 1999; 3 or more subscales or total test score in the definite difference range) or the Sensory Integration and Praxis Test (SIPT—Ayres 1989; score of <−1.0 on 3 or more subtests); and (5) parents were willing to attend 3 weekly sessions for the duration of the 10-week study period and to refrain from initiation of any new treatments including medications during the study period.

Child characteristics are also shown in Table 1 below for the treatment ($n = 17$) and UC control group ($n = 15$). In keeping with current gender prevalence estimates of ASD (CDC, 2009), the majority of the participants in both groups were boys (Treatment: 14 males, 3 females; UC: 12 males, 3 females) and Caucasian (treatment: 16 White, 1 not-reported; UC: 13 White, 2 Asian). Highest parent-reported level of education in both groups was similar, with 11 (65 %) parents in the treatment group reporting a 4-year college degree or higher, and nine (60 %) parents in the UC group reporting a 4-year degree or higher. Age, autism severity, cognitive level, and non-study related services were similar between the two groups. Non-project services, or “usual care” (UC) received during the study period was similar between the groups and documented by parents logging their child's weekly services in hours per week. Usual care included non-study related services such as speech and language services, behavioral interventions, educational program and other therapies as described in Table 1.

Overview and Timeline

Data for this randomized clinical trial were collected at a single project site in central New Jersey, between 2010 and

Table 1 Child characteristics and non-study services received

	OT/SI <i>n</i> = 17	Usual care <i>n</i> = 15	<i>p</i>
Age (mos)			
Mean (SD)	71.35 (14.90)	72.33 (10.81)	<i>t</i> (30) = 0.21, <i>p</i> = 0.84
Range	56–86	62–83	
Full scale IQ			
Mean (SD)	89.75 (18.74)	91.86 (11.93)	<i>t</i> (28) = 0.36, <i>p</i> = 0.72
Range	59–123	64–109	
Non-verbal IQ ^a			
Mean (SD)	91.87 (17.48)	95.00 (10.03)	<i>t</i> (28) = 0.60, <i>p</i> = 0.55
Range	55–119	31–79	
Verbal IQ			
Mean (SD)	93.56 (18.33)	93.79 (14.26)	<i>t</i> (28) = 0.04, <i>p</i> = 0.97
Range	63–135	69–114	
ADOS autism severity score			
Mean (SD)	7.76 (1.6)	8.40 (1.6)	<i>t</i> (30) = 1.09, <i>p</i> = 0.28
Range	5–10	6–10	
<i>Other services^a</i>			
Total behavioral treatments (ABA home, ABA school, in hours)			
Mean (SD)	8.94 (19.38)	23.3 (63.00)	U = 112.0, <i>p</i> = 0.77
Median	0	0	
Range (hours)	0–72	0–240 ^b	
Frequency of children receiving	5	3	
Occupational therapy, school (hours)			
Mean (SD)	10.95 (14.81)	10.78 (9.29)	U = 110.0, <i>p</i> = 0.50
Median	8	10	
Range	0–45	0–32	
Frequency of children receiving	8	12	
Pharmacological treatments (<i>f</i>)			
Not on medications	13	12	FET, <i>p</i> = 0.99
On medications	4	3	
Clonidine	1	0	
Antidepressant	0	3	
Methylphenidate	2	1	
Adderal	1	0	

FET fisher exact test

^a One participant randomized to treatment had a combined IQ of 65 (non-verbal IQ = 55 and a verbal IQ = 77)

^b One participant in the control group reported receiving 240 h of behavioral support in school

2012. The study was approved by the first author’s research ethics committee. Figure 1 provides an overview of the recruitment, enrollment, randomization and retention flow. Following phone screening for eligibility with interested parents, child participants were scheduled for confirmation of autism diagnosis using the ADOS and the ADI-R and, for children who did not have a current cognitive assessment (within the past 12 months) confirmation of cognitive level was also completed by the psychologist on the hospital’s autism diagnostic team. If the child met inclusion criteria, parental consent, child assent, and permission to videotape treatment sessions was obtained following the approved procedures. Next, independent evaluators, trained in the administration of the assessments, conducted the pre-intervention assessments. These blinded evaluators (*n* = 2)

were highly experienced therapists who had been licensed to practice occupational therapy for a mean of 28 years (range 26–30 years), and who had experience with working with children with ASD (mean = 19 years, range = 16–22 years). These evaluators also were trained and certified in the use of the SIPT for an average of 12.5 years (range = 9–16 years).

Following the completion of the initial assessments, the independent evaluators analyzed the assessment data (assessments are listed below) and met with the parents to identify five goals that would be addressed during the study period. These goals were scaled according to GAS Methodology (Kiresuk et al. 1994). To maintain a level of objectivity, parents did not view the goal attainment scales upon their completion or during the study period.

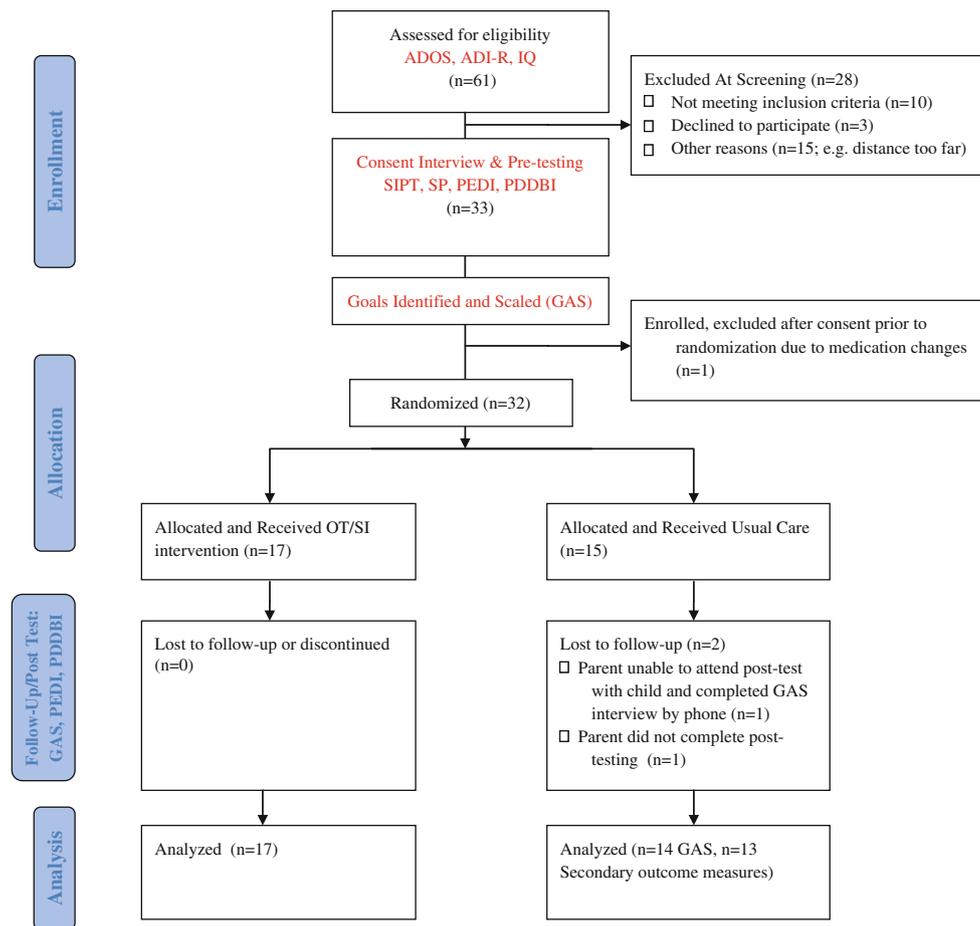


Fig. 1 Participant recruitment, enrollment, randomization and retention

Independent evaluators remained blind to child allocation during the study period and post-testing phases, and completed the post-intervention assessments using the same assessment battery.

Randomization, Allocation Concealment and Implementation

Once goals were identified and scaled, children were randomly assigned using random number generations provided by the study statistician to either the treatment or UC control group using random permuted blocks within four strata¹ based on cognitive level (hereafter referred to as IQ) and autism severity score (high IQ/high severity, low IQ/low severity, high IQ/low severity, low IQ/high severity). A high IQ was classified as a score of 85 or higher and low IQ was classified as below 84. Autism severity was determined with the ADOS using procedures to calculate severity scores described by Gotham et al. (2009), in which a lower severity

score indicates less severity of autism features. A severity score of 6–10 was scored as “high severity;” a score of 4–5 as “low severity.” In total, eight children were randomized in the low IQ/high severity strata, one child randomized in the low IQ/low severity strata, 22 randomized in the high IQ/high severity strata, and one randomized in the high IQ/low severity strata. The randomization sequence and opaque envelopes with randomization allocation group (treatment or UC) were generated by the Division of Biostatistics and remained concealed until the child’s strata was determined using the criteria outlined above. Children were randomized by the second author or principal investigator in order of completion of pre-test assessment and goal scaling. The number of days between enrollment and randomization was not significantly different between the treatment group ($M = 30.5$, $SD = 14$) and UC Control group ($M = 35.4$, $SD = 8$), $t(30) = 1.18$, $p = 0.25$.

Participant children randomly allocated to the treatment group received the intervention three times per week in 1-hour sessions for 10 weeks. All parents were instructed to continue with their child’s usual weekly treatments and to document their child’s non-study related treatments on a

¹ Although we randomized based on these strata, we did not complete subgroup analyses based on strata due to small sample size.

treatment log and to report weekly if any unusual events occurred in their child's lives (e.g. vacation, new baby). Following the study period, both groups underwent post assessment by the independent evaluators at a different location to further ensure blinding. Information on subjects' completion of allocated intervention and attrition is displayed in Fig. 1. Participant recruitment, enrollment, randomization and retention.

Intervention

Children in the treatment group received a manualized OT/SI intervention (Schaaf et al. 2011; Schaaf and Mailloux, in preparation) that followed the principles of sensory integration as outlined by Ayres (1972, 1979, 2005) and described in detail by Schaaf et al. (2009); Parham and Mailloux (2010); Parham et al. (2011, 2007); Mailloux and Smith Roley (2010); Schaaf et al. (2012); and Schaaf and Nightlinger (2007). The reader is referred to these sources for an in-depth description. The manualization of the intervention and examination of the treatment manual's adherence to fidelity was conducted in a feasibility study prior to this trial, and results are described elsewhere (Schaaf et al. 2012). Importantly, following the Data Driven Decision Making Process (Schaaf et al. 2011; Schaaf and Blanche 2012) outlined in the intervention manual, assessment data were used to develop hypotheses about the sensory motor factors affecting the child's functional behaviors and individually-tailored sensory motor activities were developed to address these factors. For example, if assessment data showed that the goal of "participate in a play activity with a peer for 10 min" may be related to poor tactile processing and praxis (hypothesis), individually-tailored sensory motor activities were designed to address tactile discrimination and improve praxis. Individually-tailored treatment activities might include activities such as using a carpeted scooter board while in the prone position to pull oneself up a ramp, then working to turn the scooter board around to ride down the ramp and land in a cushioned area of mats and pillows that are covered with various textures. In this activity, the child is experiencing total body tactile and proprioceptive sensations (from scooter board texture, actively moving muscles against resistance, and landing in textured mats and pillows) to increase body awareness and using this enhanced sensory input to plan body movements during the scooter board activity. Of note, the intervention is contextualized in play with active involvement of the child and conducted in a large gym equipped with mats, a variety of suspended swings, large balls, a climbing wall, carpeted barrels, large inner tubes and foam blocks with opportunities for active, guided, sensory motor play. The therapist facilitates the child's ability to participate in the sensory-motor experiences in adaptive ways (e.g.: use a trapeze swing to experience

proprioceptive and vestibular sensations to increase body awareness and then organize the body to hold onto the swing and jump into a large ball pit). It should be noted that this treatment is not designed to be a comprehensive treatment for autism, but rather part of a comprehensive program that includes educational, behavioral and medical services.

The intervention was delivered by three registered, licensed occupational therapists with extensive experience working with children with ASD (mean years of experience = 15, range 12–20 years), with certification in sensory integration,² and who were trained on the manualized intervention. In addition, the interventionists received 3-day training by the third author and weekly consultations with the first author to discuss challenges and questions.

Fidelity

Fidelity checks were utilized in this study to accomplish two purposes: (1) to monitor and improve provider use of the intervention manual procedures while minimizing drift in provision of services, and (2) ensure the external validity of the study procedures by documenting provider adherence to principles of intervention (Bellg et al. 2004). Treatment fidelity was confirmed using the Fidelity Measure discussed above (Parham et al. 2007). This measure has strong inter-rater reliability (0.99 for total score), with individual item inter-rater reliability ranging from 0.94 to 0.99. Validity for the measure is also strong as raters were accurately able to distinguish the manualized intervention sessions from other intervention approaches with 92 % accuracy. A score above 80/100 is considered acceptable fidelity and distinguishes this intervention from others (Parham, et al. 2007). In this study, all treatment sessions were videotaped and a random selection of 10 % (n = 51) were evaluated and rated. The mean fidelity score was 90.1 (SD = 9, Range = 53–100). Regarding the few sessions that did not reach a score of 80, additional training and consultation was provided to the therapists to support their adherence to the intervention.

Measures

Phenotypic Measures

Autism Diagnosis

Autism diagnosis was confirmed by non-study psychologists in the autism clinic at treatment site using the ADI-R

² Certification in sensory integration requires participation in 120 h of post-graduate course work offered and 40 hours of practice under the guidance of an experienced clinician trained in sensory integration (Parham et al. 2007).

(Lord et al. 1994) and the ADOS-G (Lord et al. 1999). The ADI-R is a semi-structured parent interview used to diagnose children with autism spectrum disorders and, in conjunction with the ADOS, is considered to be a gold-standard assessment for the diagnosis of ASD. The ADI-R has established validity and reliability with trained administrators (Lecavalier et al. 2006; Lord et al. 1994). The ADOS is a well-established diagnostic instrument that codes the child's behaviors during play and interactions with the examiner. This assessment also has demonstrated validity and reliability when administered by trained professionals.

Cognition

Children who met criteria for an ASD diagnosis and who were interested in the study underwent cognitive testing. Measurement of cognitive level was completed using the Stanford-Binet-V (Roid 2003), the Differential Abilities Scale-II (Elliott 2007), or the Wechsler Preschool and Primary Scale of Intelligence-III (WPPSI) (Wechsler 2003).³

Sensory Assessments

Eligible participants were evaluated by independent occupational therapy evaluators to identify and describe difficulties processing and integrating sensory information using the Sensory Integration and Praxis Test (SIPT) (Ayres 1989) and the Sensory Profile (Dunn 1999).

The Sensory Integration and Praxis Tests (SIPT) are group of 17 tests that measure a child's sensory motor abilities in the areas of tactile perception, motor planning, visual-perception, vestibular and proprioceptive processing and awareness (Ayres 1989). The SIPT is the gold standard for assessing sensory integration and praxis, and is standardized on nearly 2,000 children 4–8 years 11 months. This assessment produces standard scores for normative age groups on each of the 17 tests, was administered to all participants and findings were used to generate hypotheses about the sensory motor factors affecting the identified goals.

The Sensory Profile is a 125-item parent report of a child's sensory behaviors using a Likert-scale format to quantify the frequency of occurrence of behaviors. The Sensory Profile is appropriate for children ages 3–10 years, and was standardized on over 1,200 children with and without disabilities. Content and construct validity has been established. Responses are summarized in six sensory processing domains of Auditory Processing, Visual Processing, Vestibular Processing, Touch Processing,

Multisensory Processing, Oral Sensory Processing, five modulation areas, and three domains describing a child's emotional and behavioral responses to sensation. The Sensory Profile was administered to all participants to characterize their sensory reactivity (i.e.: over/under responsiveness, seeking or avoidance) in the areas listed above and findings were used to generate hypotheses about sensory factors affecting identified goals.

Primary Outcome Measure: Goal Attainment Scaling

Goal Attainment Scaling (GAS) provides a standardized means to capture the diversity of meaningful, functional outcomes (Kiresuk and Sherman 1968). It provides a systematic process for identification of goals that are specifically relevant to individuals and their families and has been shown to be a promising outcome measure in ASD (Ruble et al. 2012). GAS has been used extensively for outcome measurement (Ruble et al. 2010; Pfeiffer et al. 2011; Miller et al. 2007; Mailloux et al. 2007) and is shown to be a valid and reliable method for measurement of progress on individualized goals for children with ASD (Ruble et al. 2012; Palisano et al. 1992). For example, Ruble et al. (2012) report good reliability when objectives are clearly measurable finding average intra class correlation between 2 study samples of 0.98 (CI 0.74–0.99) for measurability, 0.96 (CI 0.74–0.99) for equi-distance, and 0.77 (CI 0.65–0.99) for difficulty. In a study of 65 infants ages, 3–30 months, Palisano et al. (1992) found that GAS is valid as a responsive measure of motor change for infants with motor delays as “neither type or category of goals influenced the therapists' ability to select outcomes that the infants were capable of achieving” within the 6 month intervention period (p 335). Ruble et al. (2012) concludes that GAS is a “promising ideographic approach for measuring intervention effectiveness” (p 1983). These authors recommend using a GAS template to assure goals are standardized and systematic to create reliable and valid goals, and to conduct technical checks that assess the qualities of the goal scaling to assure methodological soundness, strategies that we utilized in the current study. A technical check was completed by the second author on each GAS to assure that it met all quality markers using a technical checklist that included items based on GAS literature such as “The desired behavior/skills is observable and measurable with criteria of frequency and duration; the projected level of performance is based on the child's current level and scaled with intervals that represent equidistance.” A mathematical method is used to calculate a T-score that represents the extent to which the goals are met (Ottenbacher and Cusick 1990) and thus, although the goals are different for each participant, the score is standardized.

³ One child was tested with the Woodcock-Johnson Test of Achievement.

Goals for each child were identified by the independent evaluators using a standard series of questions with the parent and then scaled with equally spaced probability intervals according to the procedures recommended by Kiresuk et al. (1994); Ruble et al. (2012); and Mailloux et al. (2007). To scale each goal, the independent evaluator describes the child's current level of functioning for the specific goal and then scales it for expected level of attainment over the 10 week period (improvement) and down (regression). The probability distance between the levels of the scale is equal and equally distributed around the predicted level of performance. A score of "0" is used for expected level of attainment during the 10-week period, with scores of -1 and -2 denoting less and much less than expected level of attainment respectively; while $+1$ and $+2$ denote better and much better level of attainment than expected. Following the intervention period, the independent evaluators who were blind to group assignment conducted a standardized interview with the parents and asked parents to rate their child's goals. A summary of the type of goals identified by parents for this study are shown in Table 2; and a sample GAS is displayed in Fig. 2.

Secondary Outcome Measure

Pediatric Evaluation of Disability Inventory: The Pediatric Evaluation of Disability Inventory (PEDI; Haley et al. 1992) was used to evaluate a child's self-care, mobility, and social function skills. Additionally, this assessment evaluates the amount of caregiver assistance and modification that is needed for the child to participate fully. The PEDI has been used in pediatric intervention studies, and has good psychometric properties for use as an outcome measure. Construct validity has been supported (Haley et al. 1992), and it has been used in intervention studies for children with ASD (Wong et al. 2010). Additionally, the assessment has high internal consistency, and excellent inter-rater reliability.

Pervasive Developmental Disorders Behavior Inventory (PDDBI): The PDDBI (Cohen et al. 2003) is a standardized assessment normed on children with autism or PDD between the ages of 18 months and 12 years, 5 months. This assessment evaluates the severity of a child's autism behaviors on a number of parent-reported domains. For the purposes of this study, we chose a priori to evaluate a child's outcomes on the domains most aligned with the targeted focus of treatment, specifically Sensory/Perceptual Approach (S/P Approach), Ritualisms/Resistance to Change (R/R), and Arousal Regulation Problems (Arouse) domains. The PDDBI has strong parent-reported test-retest validity over a 6-month interval (S/P Approach $r = 0.63$, R/R $r = 0.82$, Arouse $r = 0.82$), and has demonstrated construct, criterion and concurrent validity.

Vineland Adaptive Behavior Scales-II (Parent Report): The Vineland Adaptive Behavior Scales II (VABS-II) (Sparrow et al. 2005) was used to assess adaptive behaviors needed for participation in home, school and community activities at pre and post assessment. The VABS-II is a standardized, norm-referenced measure that evaluates adaptive behavior in four domains: Communication Skills (Receptive, Expressive, Written), Daily Living Skills (Personal, Domestic, Community), Socialization Skills (Interpersonal Relationships, Play and Leisure, Coping), and Motor Skills (Gross, Fine). It has good subdomain reliability with approximately 75 % of subdomain scores having a value of 0.75 or greater. Inter-rater reliability is considered good for a sample aged 7–18 years, and ranges from 0.81 to 0.71 for domain and subdomain scores, and is even higher for younger children (0.83). Internal consistency is considered good at 0.80 and test-re-test reliability is high, exceeding 0.85 (Sparrow et al. 2005).

Sample Size

The study was designed to gather preliminary efficacy information about the intervention with respect to the primary outcome of GAS. For this primary outcome measure we calculated power to detect different effect sizes for a given sample size. With 32 subjects we have 78 % power to detect an effect size of 1, and greater than 80 % power to detect effect sizes greater than 1 using a two-sample t test with a two-sided type-I error rate of 5 %.

Results

Our main goal was to evaluate the effects of the intervention on parent-reported, individual goal attainment using GAS (primary outcome). Secondly, we evaluated the effects of the intervention on sensory behaviors, functional and adaptive behaviors using the PDDBI, PEDI, and the VABS II. Normality of primary and secondary outcome measures was evaluated prior to evaluating group differences. Scores on these secondary outcomes were not normally distributed and thus, non-parametric statistical tests were used to account for violation of the assumption of normality. In addition, although differences in baseline scores were not significantly different between the groups, on some outcomes differences within groups at baseline would be considered clinically meaningful. To account for variability in baseline scores, we used change scores in the analyses. Given the range of pre-treatment scores, within-person change was viewed as the most clinically relevant post-treatment score. An alpha of 0.05 was used for all comparisons. Data reported represents numbers of subjects with complete data sets (see reasons for attrition in Fig. 1).

Evaluation of Treatment Effects on Goal Attainment

To test the main effect of the treatment, we conducted a two-tailed independent samples *t*-test to evaluate the difference in goal attainment between the groups. Results

Table 2 Frequency (*f*) of goal type by study group

Type of goal	OT/SI (<i>f</i>)	Usual care (<i>f</i>)
Self-care	27	25
Play	16	15
Sitting	12	9
Daily routine participation	7	1
Fine motor	5	1
Meal participation	1	0
Community participation	4	2
Communication	2	1
Self-stimulatory behaviors	3	3
Emotional regulation	3	6
Gross motor/praxis	2	3
Safety	1	2
Sleep	1	3
Impulsive behaviors	1	0
Inappropriate touching	0	4

Sample goals (italicized portion represents goal)

The child is sensitive to auditory stimuli and wakes during the night easily. Goal: Improve auditory process as a basis for *sleeping through the night without getting out of bed for 7–8 h per night*

This child hates touching food and uses a napkin to cover his food before touching it. Goal: Decrease tactile sensitivity as a basis for *eating with his fork and spoon for 50 % of the meal as appropriate*

This child has oral-sensory sensitivity and a limited food repertoire. Goal *Decrease oral sensitivity and will try 5 new foods*

This child has dyspraxia and poor tactile processing. Goal: Improve praxis and tactile processing as a basis for *putting on socks independently*

This child has tactile sensitivity and avoids contact with others. Goal: Decrease tactile sensitivity so child can tolerate *play with sibling for 5 min without supervision*

Goal: Decrease sensory sensitivity to the oral area as a basis for tooth brushing.

Current Performance: It takes over 20 to 30 minutes each day for tooth brushing with assistance from mother. Tooth brushing is unpleasant for JH and often there is whining and crying.

-2 (much less than expected level of attainment)	Will brush teeth within a 17-20 minute time frame
-1 (less than expected level of attainment)	Will brush teeth within a 13-16 minute time frame
0 (expected level of attainment)	Will brush teeth within a 9 -12 minute time frame
+1 (better than expected level of attainment)	Will brush teeth within a 5-8 minute time frame
+2 (much better than expected level of attainment)	Will brush teeth within a 1-4 minute time frame

Fig. 2 Sample goal attainment scale

revealed a significant difference between the treatment ($M = 56.53$, $SD = 12.38$, $n = 17$) and UC ($M = 42.71$, $SD = 11.21$, $n = 14$) groups on the GAS with the treatment group achieving significantly higher scores ($t(23) = -3.23$, $p = 0.003$, $ES = 1.2$).

Evaluation of Treatment Effects on Functional Behaviors

To test the effect of the treatment on functional behaviors we compared the change from baseline to end of treatment for each of the PEDI subscales using the Wilcoxon Rank Sum test. We used median change scores to control for non-normal distributions. Results reveal significantly greater change (improvement) for the treatment group in comparison to the UC control group on Self-Care Caregiver Assistance subtest ($p = 0.008$) and Social Function Caregiver Assistance ($p = 0.039$). Of note, the treatment group also showed greater improvement on the Social Functions subtest ($p = 0.097$) and the Self-Care Functional Skills subtest ($p = 0.198$). The findings from the PEDI are displayed in Table 3. In addition to reporting median change scores, we also report mean and standard deviations for each subscale as these were used to calculate effect sizes.

Evaluation of Treatment Effects on Autism Behaviors

To test the effects of the treatment on sensory/perceptual approach behaviors, arousal regulation and ritualism/resistance to change, we compared the change from baseline to the end of treatment on these PDDBI subscales using the Wilcoxon Rank Sum test. Given that lower scores indicate a decrease in autism behaviors, a greater negative change scores indicates a better response. As shown in Table 3, there were no significant differences in autism behaviors at post-treatment between the groups, although changes for the treatment group approached significance in the Sensory Perceptual Behaviors Subscale ($p = 0.064$)

Table 3 Group differences on change in standard scores on pediatric evaluation of disabilities inventory

	Control			Experimental			Significance	Effect Size ^a
	Median	Mean	SD	Median	Mean	SD		
Functional skills^b								
Self-care	1.7	1.12	5.6	3.7	10.2	22.6	0.198	0.5
Mobility	0	6.38	15.1	0	6.57	23.8	0.69	0.0
Social	1.1	4.4	13.8	4	9.3	17.4	0.097	0.3
Caregiver assistance								
Self-care	1.3	-0.43	8.6	12.2	16.6	23	0.008**	0.9
Mobility	0	0.22	11.8	0	4.8	24.1	0.68	0.2
Social	0	-1.8	19	13.5	14.4	23.4	0.039*	0.7

^a Mean and standard deviations are based on raw scores. Effect size is presented using the difference in means divided by the pooled standard deviation

^b Functional Skills represent actual skills completed by child whereas caregiver assistance represents the amount of assistance that the caregiver provides

** $p < 0.001$; * $p < 0.05$

Table 4 Group differences on change scores of pervasive developmental disorders behavioral inventory

	Control			Experimental			Significance	Effect size ^a
	Median	Mean	SD	Median	Mean	SD		
S/P Approach	-0.05	-0.67	5.9	-5	-5.9	10.8	0.06	-0.6
R/R	-2	-1.77	6.3	-2	-6.5	13.7	0.57	-0.4
Arouse	-3	-3.3	6.0	-6	-7.1	11.6	0.38	-0.4

S/P Approach sensory/perceptual approach, R/R rituals/resistance to change, Arouse arousal regulation problems

^a Effect size is presented using the difference in means divided by the pooled standard deviation

(indicating a decrease in autism behaviors) and were also lower in the Arousal Regulation subscale (0.38).

Evaluation of Treatment Effects on Adaptive Behaviors

To test the effects of the treatment on adaptive behaviors we compared the change in standard scores from baseline to the end of treatment each of the Vineland-II subscales and the Adaptive Behavior Composite Score using the Wilcoxon Rank Sum test. As shown in Table 3 there were no significant differences in adaptive behaviors, although the treatment group improved more than the UC Controls in all subscales.

Discussion

Interventions to address difficulty processing and integrating sensory information are frequently used as part of a comprehensive approach for individuals with ASD. However, the evidence is compromised by methodological limitations in existing studies. Thus, there is a need for more evidence with a well-characterized sample using a

manualized protocol following the principles of sensory integration and measurement of fidelity. The current study is one of the first randomized trials to meet this level of rigor (Table 4).

Our main finding is that subjects with ASD who were randomized to treatment scored significantly higher on our primary outcome measure, GAS, than those who received UC. Secondly, we found that the children in the treatment group scored as needing significantly less caregiver assistance during self-care and social activities and showed a trend toward higher skills in these areas. Further, sensory behaviors in the treatment group decreased more than in the UC group and this difference approached significance (Table 5).

The primary outcome for this study was the score obtained on GAS and we found that the children receiving the treatment scored significantly higher ($p = 0.003$) than the controls on goal attainment with an effect size of 1.2. Our finding is consistent with Pfeiffer et al. (2011) who found that children with ASD who participated in 6-week program of occupational therapy using sensory integration made significantly greater gains in their individualized goal attainment scale scores in comparison to those who

Table 5 Group differences on change in in standard scores on vineland adaptive behavior scales—II

	Control			Experimental			Significance	Effect size ^a
	Median	Mean	SD	Median	Mean	SD		
Communication	1	-3.38	18.6	1	5.06	10.9	0.20	0.6
Daily living								
Skills	0	-3.0	18.5	4	4.2	11.6	0.18	0.5
Socialization	-2	-6.7	21.8	3	3.8	11.8	0.29	0.6
Composite	0	0.0	8.1	2	15.1	44.7	0.30	0.4

^a Mean and standard deviations are based on raw scores. Effect size is presented using the difference in means divided by the pooled standard deviation

received a fine motor intervention. Goal attainment scaling is a method to individualize and quantify goals for clinical populations. It has been used extensively in the clinical literature, and is recommended as an outcome measure in randomized control trials of psychosocial interventions in ASD (Ruble et al. 2012) such as the current study. Of note, the procedures we utilized in constructing scaled goals were consistent with the recently published recommendations of for its use (Ruble et al. 2012) including that: benchmarks were carefully constructed, goals were scaled at equal intervals, and rating of goals post intervention was based on parent interview by an independent evaluator blind to study condition. Although adherence to these conditions increases the reliability and validity of GAS (Ruble, et al. 2012) our findings must be interpreted with caution given that the parents were not blind to the intervention.

Two valuable aspects of GAS are that it provided a means to individualize goals based on each child's individual needs *and* to identify areas that are important to the parents. Individualization is an important aspect of treatment given the heterogeneity and developmental nature of ASD as it is likely that each child has a unique set of pre-treatment characteristics that impact the choice of goals and outcomes (Stahmer et al. 2011). Further, utilization of goals that are important and meaningful to the parents assures that the primary stakeholders (families of children with ASD) needs are being addressed. This is an important aspect of any intervention and is in keeping with contemporary trends in intervention research (PCORI 2013; Melnyk and Morrison-Beedy 2012). For the current study, individual goals were based on parent-identified areas of need and assessment data that were established prior to treatment allocation. Many of the goals for the treatment and UC controls were similar in type as shown in Table 2. The most frequent goals were related to self-care including goals such as greater independence in dressing, feeding, toileting or grooming activities (treatment = 27, UC = 25). The second and third most frequent goals were about play (treatment = 16, UC = 15); and sitting for

participation in activities such as synagogue or dinner (OT/SI = 12, UC = 9). There were some minor differences in goal type between the groups; the treatment group had more goals related to fine motor skills (OT/SI = 5, UC = 1) and participation in daily routines (treatment = 7, UC = 1); whereas the usual care group had more goals related to emotional regulation (treatment = 3, UC = 6), sleep (treatment = 1, UC = 3) and inappropriate touching (treatment = 0, UC = 4).

A second aspect of individualization that is important for ASD research and practice is that intervention strategies were tailored to each child's assessed areas of need. In this study, the Data Driven Decision Making Process (Schaaf, in press; Schaaf et al. 2012; Schaaf and Benevides 2011; Schaaf and Blanche 2012) was used to individually tailor treatment activities to address the specific sensory-motor factors that were hypothesized to be affecting each participant's goal attainment and functional skills. The treatment utilizes individually tailored sensory motor activities at the just right challenge with a playful approach to facilitate the child's adaptation to promote function. Thus, the focus of treatment is on each individual's sensory motor factors hypothesized to be impacting function, but importantly, the expected outcomes are functional behaviors. It is likely that this individualization was an important aspect of the positive findings of this study, and should be modeled in future studies.

In terms of functional behaviors, the children in the treatment group significantly decreased their need for caregiver assistance on self-care and social activities in comparison to the UC controls on the PEDI. In addition, they also showed a trend toward improvement in self-care and social skills. Thus, not only did the caregivers rate the children in the treatment group as needing less assistance from them in these activities, they also rated their skill level higher. These secondary outcome data should be interpreted with caution given that we completed multiple comparisons, however, these findings are consistent with the philosophy of the treatment approach—that adequate processing and integration of sensory information provides

an important foundation for participation in functional, meaningful activities (Ayres 2005). Of note, the PEDI has been shown to have good reliability and validity as an outcome measure of functional behaviors (Nichols and Case-Smith 1996).

In terms of the sensory-motor factors that may underlie these findings, in this cohort many participants in both groups showed deficits in sensory modulation and praxis (measured via the Sensory Profile and the SIPT), and thus, the intervention was tailored to address these areas. Improvements in sensory modulation and praxis skills therefore, may underlie the gains seen in self-care and social skills. In regard to sensory modulation (over or under-reactivity to typical levels of sensation), the individually-tailored treatment for these children included a focus on activities that facilitated sensory modulation and regulation of behavioral responses to these sensory experiences. As the child's ability to modulate sensation improved, it is likely that their behavioral regulation also improved and subsequently they were better able to participate in self-care and social activities. Interestingly, the subjects in the treatment group did show a decreasing trend of negative sensory behaviors on the Sensory Perceptual Behaviors Subscale of the PDDBI and this approached significance ($p = 0.064$), supporting this interpretation.

Similarly, it is possible that the intervention also had an impact on praxis. Praxis involves the ability to conceive of, plan, and organize goal-directed motor actions (Ayres 1989; Dziuk et al. 2007) and is related to adequate processing and integration of body sensory information (tactile, vestibular and proprioception). The intervention aimed to facilitate body awareness and praxis through individually-tailored, active, sensory-motor activities rich in tactile, proprioceptive and vestibular sensations. Many self-care activities such as dressing require adequate body awareness and thoughtful planning and execution of motor skills. Thus, it is possible that improved body awareness and praxis had a positive impact on ability to carry out these self-care tasks. Similarly, social interactions require constant processing of varied, often unpredictable sensations and the need for spontaneous responses (i.e.: praxis) and are likely affected by difficulty processing and integrating sensory information related to the body (Hilton et al. 2007, 2010; Baker et al. 2008; Ashburner et al. 2008; Reynolds et al. 2011; Watson et al. 2011; Hochhauser and Engel-Yeger 2010). Thus, as the children's praxis improved, it is plausible that their ability to adaptively plan and carry out social interaction activities also improved and they became more independent. Further testing of these potential relationship is needed and in order to validate the idea that improvements in sensory modulation and praxis were related to improvements in functional skills, it will be important in future studies to specifically measure any

changes in these factors and their relationship to changes in functional skills such as self-care and socialization. In this study we were limited by the lack of instruments validated to measure change in these factors for this population within our 10-week intervention period. The SIPT is not recommended as a pre-post-test measure for periods shorter than 8–12 months (Ayres 1989) and its utility for shorter intervention periods has not been tested. Similarly, the Sensory Profile has not been validated for use as a pre-post assessment (Dunn 1999) although there is emerging data that test–retest reliability of certain sub-scores may be utilized in this way. Until these measures are validated for use as outcome measures in shorter intervention periods, or outcome measure to evaluate change in sensory functions are validated, future studies should consider a longer intervention period so that these assessments can be used to measure change in sensory-motor skills and determine their relationship to any changes in functional skills and adaptive behavior.

In terms of the proposed mechanism underlying the positive findings in this study, one explanation is that the intervention impacted neuroplasticity—the ability of the nervous system to be shaped and influenced by experience. It is well regarded in the neuro-developmental literature that early sensory motor experiences promote neuroplasticity and enhance the capacity of the brain to adapt to environmental challenges (Shonkoff and Phillips 2000; Ayres 1972; Dawson et al. 2012). Thus, it is possible that through the process of neuroplasticity that the children became more independent in their functional skills as their ability to process and integrate sensory information improved. Further testing of this assumption is needed using methods that evaluate nervous system activity pre and post intervention. There is some preliminary evidence that change in neural activities results from enriched environments. For example, Dawson et al. (2012) showed that more organized EEG activity occurred in children with ASD who also made gains in the Denver Early Start Program; and Miller et al. (2007) showed that electrodermal activity, a measure of sympathetic nervous system activity, showed a trend to decrease (expected direction) following a sensory-enriched intervention in subjects who were previously sensory hyper-reactive. An important next step in this research will be to measure changes in brain activity that may be concurrent with improvements in adaptive behaviors and individual goals as suggested by Schaaf et al. (2013).

In summary, our data provide preliminary support for the efficacy of a manualized intervention designed to address difficulties processing and integrating sensory information for children with ASD. We show improvements in our primary outcome—Goal Attainment as well as our secondary outcome measures showing improvements in self-care and social activities reflected by

decreased caregiver assistance. These findings should be interpreted cautiously until they are replicated in a larger sample size. In addition, in future studies it would be useful to include additional outcome measures that rely on direct observation of goal attainment and sensory behaviors to provide further validation of GAS findings. It will be important to supplement parent reported data with direct observational measures. It will also be important to include a longer intervention period in future studies and follow-up testing to determine if the observed changes are maintained. Finally, although we randomized subjects based on autism severity and cognition, we were not able to include these strata in our analysis due to our sample size. Future studies would be strengthened by the inclusion of a larger sample so that impact of potentially confounding variables on treatment outcomes can be evaluated. Of note, almost all of our participants (30 of 32 children, or 94 %) demonstrated high severity of autism, and 22 or 68.75 % also had high IQ. It would be useful if future studies utilizing this intervention include children with low severity and/or low cognition to determine if the findings from this study are replicated with this sample. Similarly, our sample of convenience resulted in a sample with little ethnic diversity and future studies should make an effort to include participants from more diverse backgrounds. Despite these limitations, this study provides evidence that this intervention may be a useful adjunct to a comprehensive intervention program for individuals with ASD who have functional and behavioral challenges related to difficulty processing and integrating of sensory information.

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Interventions That Address Sensory Dysfunction for Individuals with Autism Spectrum Disorders: Preliminary Evidence for the Superiority of Sensory Integration Compared to Other Sensory Approaches

Roseann C. Schaaf

ABBREVIATIONS

ADOS	Autism Diagnostic Observation Schedule	MANOVA	Multivariate analysis of variance
ANOVA	Analysis of variance	PDD	Pervasive developmental disorder
ASDs	Autism spectrum disorders	PPVT	Peabody picture vocabulary test
DBC	Developmental behavior checklist	SD	Sensory dysfunction
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, 4th edition	SSED	Single subject experimental design
GSR	Galvanic skin response	SSQ	Sound sensitivity questionnaire
ICD-10	International Classification of Diseases and Related Health Problems, 10th edition		

INTRODUCTION

It is estimated that 80–90% of individuals with autism spectrum disorders (ASD) demonstrate sensory-related problem

behaviors such as self-stimulating behaviors (finger flicking or excessive rocking), avoiding behaviors (such as placing hands over ears in response to typical levels of auditory input), sensory seeking behaviors (twirling, chewing, etc.), "tuning out" behaviors such as not responding to their name or other environmental cues, and difficulty enacting purposeful plans of action (Baranek et al. 2006; Huebner 2001; Kientz and Dunn 1997; O'Neill and Jones 1997; Ornitz 1974, 1989; Rogers et al. 2003; Tomchek and Dunn 2007). These behaviors, which may have a sensory basis, are termed sensory dysfunction (SD) and findings show that they limit participation in play, social, self-care and learning activities (Adrien et al. 1987; Baranek 1999, 2002; Edelson et al. 1999; Grandin 1995; Leekam et al. 2007; McClure and Holtz-Yotz 1991; Leekam et al. 2007, 1997; O'Riordan and Passetti 2006; Ornitz 1974, 1989; Rapin and Katzman 1998; Rogers and Ozonoff 2005; Schaaf et al. 2010; Williams 1992, 1994). Although interventions for SD are among the most requested services for children with ASD (Mandell et al. 2005; Green et al. 2006), there is limited evidence about their efficacy (Baranek et al. 2006; Dawson and Watling 2000; Rogers and Ozonoff 2005). The National Research Council (2001, p. 131) reports that there is a "pressing need for more basic and applied research to address the sensory aspects of behavior problems (in children with ASD)." Baranek (2002) also stressed that "best practice" for children with ASD should include interventions to address SD, but that more research is needed to guide parents, teachers, and other professionals to make informed decisions about intervention. Most studies to date fail to link basic science findings to behavioral or functional changes, and thus, it is not possible to determine the specific processes underlying behavioral gains reported in intervention studies. The purpose of this chapter is to define and describe SD in ASD, evaluate the evidence for current interventions that

address SD in ASD, and discuss practice recommendations in light of these data.

WHAT IS SENSORY DYSFUNCTION IN ASD?

Courtney is a six-year-old child diagnosed with ASD who attends a public school in a semi-inclusive classroom for children with special needs. Today, like most other days, Courtney is having difficulty participating in the class activities. The teacher already reprimanded Courtney several times this morning for "fidgeting" in her seat during circle time, disrupting the other children by making silly noises with her mouth and constantly getting up to wander about the room. During snack time, at 10 am, Courtney has an outburst and refuses to eat the graham crackers and milk provided by the school. The ticklish sensation of the milk on her lips is bothersome and the graham crackers are "too rough" for her liking. Instead of participating in snack time, Courtney sits by herself. During morning recess at 11 am, Courtney keeps to herself and is afraid to play on the slide with the other children. Finally, she runs to the swings and uses them to spin in circles. At 11:30 am, when the lunch bell rings, Courtney places her hands over her ears and runs into the closet, bothered by the noise. A classmate tries to comfort her but Courtney shoves the girl away and hurts her. In the cafeteria, Courtney becomes increasingly agitated. She sits alone with her hands over her ears until she feels able to negotiate the lunch line. After the crowd subsides, with the help of the classroom aide, Courtney manages to select a few items from the menu and place them on her tray. On the way back to her seat, Courtney trips over a backpack lying in the aisle and spills her tray. The other children begin to laugh. Courtney runs from the cafeteria with her hands covering her ears.

The teacher finds her in the gym wedged under several gym mats that she has piled on top of herself. Her hands are over her ears and she is rocking.

Courtney is a child with ASD and a SD that contributes to her disability. Families indicate that SD is one of the most significant factors limiting their ability to participate in home and community activities (Mandell et al. 2005). For example, one parent of a child with ASD and SD stated, "(After) our last commercial flying experience, we both swore off of it. Never again. His sensory sensitivity made it unbearable. He was just inconsolable." (Benevides et al. 2010). Others indicate that they must orchestrate their family routines and outings to accommodate the child's SD. They are unable to participate as a family in mealtimes (they must feed the child with ASD earlier than the others due to food sensitivities), family outings such as going to the movies are impossible (the child is unable to tolerate typical levels of noise and stimulation of crowds), or socialization with friends ("our child's self-stimulating behaviors make it impossible to be comfortable visiting with friends or meeting other children for a play date") (Larson 2006; Schaaf et al. (in press); Schaaf and Nightlinger 2007). Self-reports from individuals with ASD confirm these findings and are particularly potent in their descriptions of the impact of SD on participation in daily life activities (Grandin 1995; O'Neill and Jones 1997; Williams 1992, 1994). These self-reported data portray how SD limits the ability of individuals with ASD to participate fully in society. For example, Temple Grandin, a high functioning woman with ASD, articulates how her unusual processing of auditory, visual, and tactile information impedes social conversation because she is over-stimulated and distracted by the non-essential stimuli (Grandin 1995). As a result, she does not enjoy or participate in many of the daily activities of her peers.

INTERVENTIONS TO ADDRESS SENSORY DYSFUNCTION

It is widely accepted that a comprehensive educational program for children with ASD is the most effective in achieving optimal outcomes (National Research Council 2001). In addition to educational, speech and language, and behavioral services, a comprehensive program for individuals with ASD often includes occupational therapy services to address SD and other sensory-motor delays. In fact, Mandell et al. (2005) and Green et al. (2006) found that occupational therapy to address SD is among the top three services requested by families of children with ASD. Schwenk and Schaaf (2003) found that 99% of the therapists surveyed who work in public school settings with children with ASD used strategies to address SD as part of their therapeutic approach.

Occupational therapists follow a professional clinical reasoning framework to evaluate and design interventions for children with SD. Treatment follows a well-documented theoretical framework (Ayres 1979, 1989; Schaaf et al. 2010) directed by a set of principles that guide the therapists' clinical reasoning and interactions with the child (Schaaf and Miller 2005). The therapist chooses individually tailored sensory-motor activities for the child based on areas of need identified by systematic assessment. For example, for a child who is constantly rocking in his seat, systematic assessment might suggest a greater need for vestibular input. To address this issue the therapist generally takes a three-pronged approach:

- Work directly with the child using specialized equipment in a clinic that allows the child to experience vestibular input such as swings, bolsters, or scooter boards

- Provide environmental adaptations such as a small inflated cushion for the child to sit on in the classroom (thereby providing needed vestibular input and decreasing disruptive rocking behaviors)
- Provide consultation to the parent or teacher, for example, to suggest that the school team provide greater opportunities for the child to access playground equipment, such as swings, to provide regular intervals of the needed input and thus decrease the rocking behaviors (environmental adaptation)

It is worth noting that the prescribed activities are meaningful to the child (i.e., developmentally appropriate and contextualized in play) and embedded within the daily routine when possible. The therapist maintains data on whether these strategies are effective in reducing the disruptive behaviors and improving the child's attention and participation in class or home and community activities. Thus, by engaging the child in individually tailored sensory-motor activities, it is hypothesized that the child's nervous system is better able to modulate, organize, integrate and utilize information from the environment, and thus, is not driven to seek or avoid sensation in maladaptive ways. Adequate processing of sensory information, in turn, provides a foundation for further adaptive responses and participation in activities through adaptive neuroplastic mechanisms (Baranek 2002). Parent education and environmental adaptations are provided in tandem with direct intervention to support the child's sensory-motor needs.

This approach is child-centered and provides a just-right challenge (scaffolding) to facilitate progressively more sophisticated adaptive sensory-motor responses while engaging the child in affectively meaningful and developmentally appropriate play interactions. The child's focus is intended to be placed on

play (intrinsically motivated) and not on cognitive-behavioral strategies or repetitive drills; thus, gains made during treatment are expected to be generalized to everyday life situations. Treatment goals focus on improving the ability to process and utilize sensory information, so that the child can develop better sensory modulation for attention and behavioral control, or the ability to form perceptual schemas and practical abilities as a foundation for greater participation in school, social, and daily living activities (Baranek 2002; Mailoux 2006). Thus, the sensory-integrative approach is utilized within a professional domain of practice, such as occupational therapy, and is focused on improving the child's participation in activities through the use of individually prescribed sensory motor activities.

Although this approach is based on solid theoretical principles that are contextualized within the professional framework of occupational therapy (Baranek 2002;), there is no manualized protocol and, thus, its utility and efficacy has not been systematically tested. Therefore, the evidence to support this approach is sparse and the studies that do exist have methodological flaws including that they do not explicitly describe the intervention and do not have a measure of fidelity, making it difficult to determine if the intervention provided was in keeping with the theoretical principles of the sensory-integrative approach. Evaluation of the evidence that does exist is further complicated by the fact that there are several techniques that utilize sensory stimulation but are not in keeping with the sensory-integrative approach and which are confused with it (Cox et al. 2009). These techniques usually provide passive stimulation to one sensory system rather than the holistic, child-directed, playful approach to intervention that is contextualized within a professional framework that is the hallmark

EVIDENCE FOR THE SENSORY-INTEGRATIVE APPROACH

Like many other therapeutic interventions utilized with children with ASD, solid evidence for interventions to address SD in ASD is just beginning to surface and data

of the sensory-integrative approach. The sensory-integrative approach is guided by the set of principles outlined in Table 9.1 (Parham et al. in press). The reader is referred to the work of Schaaf et al. (2010) for a full description of the sensory-integrative approach and the principles that guide the intervention.

TABLE 9.1 Principles of Ayres sensory integration (Adapted from Parham et al. in press)

Item	Description
Ensures physical safety	The therapist anticipates physical hazards and attempts to ensure that the child is physically safe through manipulation of protective and therapeutic equipment or the therapist's physical proximity and actions. An existing safe room is important as is the therapist's attention to the child's abilities and potential dangers.
Presents sensory opportunities	The therapist presents the child with at least two of the following types of sensory opportunity, tactile, vestibular, or proprioceptive, in order to support the development of self regulation, sensory awareness, or movement in space.
Helps attain appropriate levels of alertness	The therapist helps the child to attain and maintain appropriate levels of alertness, as well as an affective state that supports engagement in activities.
Challenges postural, ocular, oral and bilateral motor control	The therapist supports and challenges postural control, ocular control, or bilateral development. At least one of the following types of challenge are intentionally offered: postural, resistive whole body, ocular-motor, bilateral, oral, or projected action sequences.
Challenges praxis and organization of behavior	The therapist supports and presents challenges to the child's ability to conceptualize and plan novel motor tasks, and to organize his or her own behavior in time and space.
Collaborates in activity choice	The therapist negotiates activity choices with the child, allowing the child to choose equipment, materials, or specific aspects of an activity. Activity choices and sequences are not determined solely by the therapist.
Tailors activity to present a just-right challenge	The therapist suggests or supports an increase in complexity of challenge when the child responds successfully. These challenges are primarily tailored to the child's postural, ocular, or oral control; sensory modulation and discrimination; or praxis developmental level.
Ensures that activities are successful	The therapist presents or facilitates challenges that focus on sensory modulation or discrimination; postural, ocular, or oral control; or praxis, in which the child can be successful in making an adaptive response to challenge.
Supports intrinsic motivation to play	The therapist creates a setting that supports play as a way to fully engage the child in the intervention.
Establishes a therapeutic alliance	The therapist promotes and establishes a connection with the child that conveys a sense of working together towards one or more goals in a mutually enjoyable partnership. The therapist and child relationship goes beyond pleasantries and feedback on performance such as praise or instruction.

are mainly from case reports, studies using single subject experimental designs (SSED), or small group design studies. To access available studies, we utilized Ovid Medline, PsychInfo, and OTSearch from 1995 forward using the search terms of "sensory integration," "sensory therapy," "sensory occupational therapy," "occupational therapy sensory integration," "auditory integration training," "vestibular therapy," "brushing," "visual therapy," "tactile therapy," "tactile treatment," "deep pressure," "and pressure vest." We have included one classic study of the sensory-integrative approach that dates back to 1980 because it was completed by the author of the sensory integration theory and thus we felt that it was important to include (Ayres and Tickle 1980). Our search yielded studies using both the sensory-integrative approach and sensory stimulation techniques.

In the following sections, we report first on studies of intervention using a sensory-integrative approach and then on those that used a sensory stimulation technique.

Table 9.2 lists the studies that utilized the sensory-integrative frame of reference within occupational therapy, specifically investigated interventions for SD, and show emerging evidence. Collectively, they report that individuals with ASD and SD who receive occupational therapy using a sensory-integrative approach demonstrated gains in play, individualized goals, and social interaction (Ayres and Tickle 1980; Case-Smith and Bryan 1999; Linderman and Stewart 1999; Schaaf and Nightlinger 2007; Watling and Dietz 2007) and a decrease in sensory symptoms (Smith et al. 2005; Fazlioglu and Baran 2008).

Schaaf and Nightlinger (2007) case study reports on a child who received occupa-

TABLE 9.2 Studies that investigate the use of sensory integration in occupational therapy in children with ASD

Study	Participants	Outcome	Evidence-based rating	Discussion
✓ Ayres and Tickle 1980	N= 10 mean age 7.4 years with ASD	Subjects with average- to hyper-responsive patterns to the stimuli (e.g., touch, movement, gravity, and air puff) showed better outcomes than those with a hypo-responsive pattern.	Weak	Descriptions of participants, intervention and outcome measures are not clearly provided.
Case-Smith and Bryan 1999	N= 5 males aged 4-5;3 with autism	Independent coding of videotaped observations of free play indicated that three of the five boys demonstrated significant improvements in mastery play and four demonstrated less "non-engaged" play.	Adequate	<ul style="list-style-type: none"> • Clear descriptions of the participants, the outcome measures and the intervention are provided. The data analysis is linked to the research questions. Use of visual inspection is relevant and appropriate. • However, detailed information on the intervention is not provided and generalizations of the findings are limited by the (single subject) design.

(Continued)

TABLE 9.2 (Continued)

Study	Participants	Outcome	Evidence-based rating	Discussion
Linderman and Stewart 1999	<i>N</i> = 2 aged 3;3 and 3;9 with mild and severe ASD, respectively	Participant 1 (who was noted to have tactile hypersensitivity) demonstrated gains in all intended outcomes (social interactions, approach to new activities, and response to holding). Participant 2 (who had both hypo-responsiveness to vestibular and hyper-responsiveness to tactile sensations) made gains in activity level and social interaction, but not in functional communication.	Adequate	<ul style="list-style-type: none"> Participant characteristics are described. The dependent measure is described and can be replicated. The baseline measurement is adequate. The analysis uses visual inspection. The inter-rater reliability has Kappa of .63. There is good social validity as it measures functional behaviors during daily activities. However, there is no specific information about the diagnoses or the treatment; no consideration is given to the effect of other interventions; the sample size is small and homogenous; there is no fidelity measure; and raters are not blind to condition.
Smith et al. 2005	<i>N</i> = 7 (four males, three females) aged 8–19 years diagnosed with PDD	Videotape analysis of 15 min and 1 h after intervention showed a decrease in the frequency of self-stimulating behaviors. Teachers reported fewer self-stimulating behaviors and self-injurious behaviors during the treatment phase.	Adequate	<ul style="list-style-type: none"> Intervention is described and is in keeping with the principles of sensory integration. However, the sample was small and homogenous; there was no fidelity measure and no mention of whether the raters were blinded as to the treatment and control weeks.
Schaaf and Nightlinger 2007	<i>N</i> = 1 (male) 4 years of age with ASD	Measurable improvements were observed in individual goals and in post-treatment testing of sensory processing. Qualitative data (parent interview) also reported striking improvements in child and family's participation in activities and outings.	Adequate	<ul style="list-style-type: none"> Intervention is detailed in a replicable way and follows the theoretical principles of the sensory integrative approach. Outcomes have social validity (child gains had an impact on his everyday life and the mother was extremely satisfied with the results). However, findings cannot be generalized, there is no measure of fidelity and the rater is not blind to intervention.

(Continued)

TABLE 9.2 (Continued)

Study	Participants	Outcome	Evidence-based rating	Discussion
Watling and Dietz 2007	N=4 males aged 3 and 4; 4 with ASD	There were improvements in ability to handle transitions, socialization, compliance and behavioral regulation. No decrease in undesirable behavior or increase in engagement was found.	Adequate	<ul style="list-style-type: none"> Participant characteristics are described in detail. Dependent and independent variables are identified. There is a reliable measurement of fidelity. The comparable condition (a play scenario) is well described, activity choices are individualized and presented in a random order and dependent variables are described in detail and are individually determined. There is good procedural reliability and social validity. However, specific diagnostic information is missing; there is a limited use of standardized test scores; detailed information on the intervention is not provided; and generalizations of the findings are limited by the (single subject) design.
Fazlioglu and Baran 2008	N=30 children aged 7-11 years old diagnosed with autism according to the DSM-IV criteria	Statistically significant differences were recorded in the Sensory Evaluation Form for Children with Autism, with the treatment group $p < .05$.	Adequate	<ul style="list-style-type: none"> Subject randomization is valid; the protocol for intervention is described in a manner that can be replicated (the principles and philosophy are described); data analysis is linked to the research questions and there is good social validity. However, there is no fidelity measure or mention of whether the raters were blind to the group assignment.

tional therapy using a sensory-integrative approach and showed improvements in the hypothesized direction in several behaviors. The child in this study demonstrated

improved motor skills, social skills, and adaptive behaviors (e.g., improved ability to tolerate foods and thus improved participation in mealtime with the family, as

measured by individual Goal Attainment scales, and decreased SD, as measured by the sensory profile scores and individual Goal Attainment scales). The results obtained were consistent with anecdotal reports from parents and other sources describing how quality of life for the family improved because the child's sensory over-responsive behaviors decreased and his ability to tolerate and participate in family activities improved (e.g., he was able to maintain self-regulation during grooming activities and to interact with other children during community playgroup activities). This study is promising in terms of its evidence for a sensory-integrative approach for ASD as it details the intervention in a replicable way and demonstrates how the intervention follows the theoretical principles of the sensory-integrative approach. In addition, the outcomes have social validity in that the child made gains that had an impact on his everyday life and the mother was extremely satisfied with the results. However, the study is limited in that it is a case study report, there is no measure of fidelity, and the rater was not blind to intervention.

Fazlioglu and Baran (2008) using a randomized two-group design, this study found statistically significant ($p < 0.05$) improvements between the groups in sensory-related behaviors pre- and post-intervention as measured by the Sensory Evaluation Form for Children with Autism. The study used a combination of sensory integration strategies (individually designed vestibular, somatosensory, and other sensory activities where the child was an active participant) and a "sensory diet" (systematically applied sensory stimuli) with 30 children diagnosed with low-functioning autism according to the criteria of the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSM-IV-TR; APA 2000). This study is promising in terms of its evidence for a sensory-integrative approach for ASD as the subject randomization is valid, the protocol for intervention is described

in a manner that can be replicated (the principles and philosophy are described), the data analysis is linked to the research questions, and there is good social validity. However, there is no fidelity measure or mention of whether the raters were blind to the group assignment.

Smith et al. (2005) study considered seven subjects with ASD, aged 8–19 years. The study utilized a single subject withdrawal design (A–B–A–B) where weeks 1 and 3 represented the control sessions (30 min/day of table-top activities) and weeks 2 and 4 were the treatment sessions consisting of 30 min per day for 5 days per week. They video recorded the participants and performed frequency counts for presence and number of self-stimulating behaviors. They found that the overall frequency of self-stimulating behaviors decreased over the 4 weeks. Teachers also reported fewer self-stimulating and self-injurious behaviors during the treatment. This study was promising in that it describes the intervention and it is clear that it was in keeping with the principles of sensory integration (Smith et al. 2005, p. 421):

Subjects engaged in sensory based treatment that included a variety of tactile, proprioceptive and vestibular input, based on their unique sensory needs. This is distinguished from sensory stimulation programs in that treatment was individualized based on assessment results, and the type or types of sensation and specific activities used.... Vestibular, tactile and proprioceptive based activities were primarily used, which is consistent with the accepted characteristics of intervention.

However, the study was limited by the small, homogenous sample and lack of a fidelity measure. In addition, there was no mention as to whether the raters were blinded to the treatment versus control weeks.

Linderman and Stewart (1999) study used a single subject A–B design to explore the effects of occupational therapy using

a sensory-integrative approach on the functional behaviors of two young children (aged 3 years 3 months and 3 years 9 months) with pervasive developmental disabilities (PDD). They used the revised Functional Behavioral Assessment for Children with Sensory Integrative Dysfunction (Cook 1991) to evaluate the duration, quality and frequency of targeted sensory behaviors. Participant 1 demonstrated major improvements in social interactions, approach to new activities and responses to hugging and holding. Participant 2 displayed improvements in social interaction and response to movement. Although the authors state that treatment was in keeping with the sensory-integrative principles (i.e., child-directed treatment and active participation of the child) there is no specific information about the treatment, no consideration was given to the effect of other interventions (e.g., one subject enrolled in a preschool and another started a vitamin regimen), and the sample size was small and homogenous.

Case-Smith and Bryan (1999) conducted a study with a single subject A-B design of five subjects with autism, at 4 and 5 years of age. Baseline measures of play, non-engaged behaviors, child-adult interactions, and peer interactions were obtained via video-coding for a 3-week period. Data were analyzed by plotting behaviors on line graphs, computing means for each phase, and then calculating regressions for each phase. Data from each phase were compared using the Wilcoxon signed rank test to assess differences in the means for each phase. Results were mixed as there were improvements in some areas but not in others. For example, following intervention, three of the five children showed significant improvements in mastery play, four of the children demonstrated significantly decreased non-engaged behaviors, and only one participant demonstrated a significant increase in adult interactions.

None of the participants demonstrated significant increases in peer interactions. Despite the mixed findings, this study is promising in that it clearly describes the participants and the outcome measures and the intervention is described in detail. The data analysis is linked to the research questions and use of visual inspection is relevant and appropriate.

Watling and Dietz (2007) study used a withdrawal SSED (A-B-A-B) with four boys between the ages of 3 and 4.4 years of age who were diagnosed with ASD (criteria for diagnosis not known) to examine the immediate effects of occupational therapy using a sensory-integrative approach (Ayres Sensory Integration¹) on undesirable behaviors and engagement. Target behaviors were operationalized and coded. The target behaviors included: changes in individually defined undesirable behaviors that interfere with task engagement and participation in daily activities; and engagement defined as intentional, persistent, active, and focused interaction with the environment, people and objects. The study consisted of familiarization, baseline phase 1 and treatment phase 1, followed by baseline phase 2 and treatment phase 2. Baseline consisted of developmentally appropriate toys selected individually for each child. Intervention consisted of three, 40-min sessions of Ayres Sensory Integration per week followed by a 10-min table-top activity segment during which outcome data was collected. Data for each subject were plotted on a line graph and interpreted through visual inspection. In addition, data in a study log from researchers and weekly reports of the participant's behavior in the home environment were reviewed. Visual inspection of the data for undesirable behaviors and engagement indicates considerable overlap in the number of intervals in which the behavior was observed in all phases; thus, Ayres Sensory Integration did not have a significantly different effect from the play scenarios

on target behaviors. Data from study logs suggested that the intervention had a positive effect on transitions, socialization, compliance, and general behavior regulation, however, given the anecdotal nature of this data, the findings from this study cannot be interpreted to provide evidence for Ayres Sensory Integration. This study was promising in that participant characteristics were described in detail and dependent and independent variables were identified, however specific diagnostic information was missing and there was limited use of standardized test scores other than the Sensory Profile score that was used as an inclusion criterion. The information on the intervention was not provided except to mention that it followed the Ayres Sensory Integration approach. There was reliable measurement of fidelity. The comparable condition (a play scenario) was well described, the activity choices were individualized and presented in a random order, and the dependent variables were described in detail and also individually determined. There was good procedural reliability (above 99% for all phases). The social validity of this study was good in that dependent variable behaviors were identified based on parent interview and the data from study logs indicates an impact on daily life, however, the generality of the findings are limited by the design (single subject).

Ayres and Tickle (1980) study investigated whether the type of sensory processing disturbance predicted the response to sensory-integrative therapy. The subjects were ten children with autism aged between 3.5 and 13 years (mean age was 7.4). Subjects' responses to sensory input were evaluated through the use of a test constructed by the researchers solely for this purpose. The test consisted of 14 specific sensory stimuli (e.g., response to light touch, response to pain, and response to sound of white noise) and rating was on a scale of 1-5 (no reaction to definite

over-reaction). The test was administered by the investigator at least twice to enhance accuracy. Intervention was 1 year of occupational therapy using a sensory-integration approach "that focused on carefully providing somatosensory and vestibular sensory experiences and on eliciting an adaptive response to these stimuli" (Ayres and Tickle 1980, p. 378). Results were reported by individual subject changes on the test of responses to specific sensory stimuli and, in some cases, post-test scores on motor performance and vocabulary tests. A stepwise discriminant analysis was conducted to determine the parameters that best discriminated between subjects who were good responders to therapy versus those who were not. The good versus the poor responders had statistically significant ($p < 0.05$) differences on the presence of tactile defensiveness. There were no significant differences in the proposed direction for reactions to touch pressure, vibration, and movement. The best discriminators between the good and the poor responders were tactile defensiveness, reaction to movement, gravitational insecurity, and reaction to an air puff. Subjects who had normal or over-reactions to stimuli were better responders to therapy than non-responders. This study is interesting in that it is one of the first studies conducted to evaluate the effects of the sensory-integrative approach for children with autism and provides some preliminary data suggesting that children who are over responsive to stimuli will respond better than those who are under responsive. However, the study was weak in that it failed to adequately describe the participants' characteristics and the independent variable (treatment) was not described. The dependent variables (measures) did not have reliability or validity, there was no comparison condition, and there was no calculation of power. The study has high social validity in that it is an area of high interest for clinicians and

serves to provide preliminary guidelines for future studies in this area.

Conclusion

Although these studies provide promising evidence, it is not possible to draw strong practice implications because of small sample sizes, failure to adequately characterize the sample, lack of a detailed, replicable intervention protocol with a fidelity measure, and other methodological and design flaws. Future studies must address these issues and, fortunately, several efforts are underway to do so. For example, a Fidelity to Treatment Measure has been developed to evaluate whether intervention follows the sensory-integrative principles established in the literature (Parham et al. 2007). This fidelity scale evaluates constructs related to sensory-integration interventions, details the training of the people administering the intervention, and specifies the environment in which the treatment is conducted. It will ensure that future studies evaluating the sensory-integrative approach attain rigorous standards that include fidelity. A pilot version of this fidelity scale was used in the Watling and Dietz (2007) study. A manualized protocol has also been developed and is being tested for its utility and effectiveness for SD in ASD (Schaaf et al. in preparation). This manual is in keeping with the recommendations in the literature for intervention with the ASD population as outlined by Lord et al. (2005): it outlines key theoretical principles; it describes the objectives for each principle; it describes the clinical reasoning for each principle; and it is flexible in its application to allow for individualization of the treatment – an important aspect of interventions for ASD. An earlier version of the manual was used in a randomized pilot study for a non-ASD group (Miller et al. 2007; Miller et al. 2007). The findings show that, following a 10-week, 30-session intervention, children

in the treatment group ($n=7$) made gains that were significantly greater than the children in the other two groups (no treatment ($n=10$) and active control ($n=7$)) on Goal Attainment scales ($p<0.01$). They also increased more than the other groups on attention, measured by Leiter-R (Roid and Miller 1997), with $p=0.03$ compared to $p=0.07$ for no treatment. Data showed trends in the predicted direction for the treatment group on sensory behaviors and the cognitive/social composite score on the Leiter-R. The treatment group showed a trend toward greater reduction in electrodermal activity (a measure of sensory responsivity) than the other groups.

Finally, to address the need for sensitive, meaningful outcome measures that are function-oriented and in keeping with the principles of the sensory-integrative approach, Goal Attainment Scaling (Kiresuk et al. 1994) has been adapted and applied for use with the sensory-integrative approach (Mailloux et al. 2007). Goal Attainment Scaling provides a means to monitor intervention goals that are specifically relevant to individuals and their families and thus holds promise as an effective, replicable outcome measure to evaluate the efficacy of the sensory-integrative approach for individuals with autism. The Goal Attainment scale provides a mechanism for assuring that outcomes have high social validity.

EVIDENCE FOR SPECIFIC SENSORY TECHNIQUES

A number of studies examine the effects of specific sensory strategies on reducing self-stimulating behaviors, improving attention and engagement in tasks, and decreasing sensory aversions for individuals with ASD. To reiterate, these interventions should be distinguished from the sensory-integrative approach in that they utilize stimulation of one specific sensory system rather than

the holistic, integrated approach that is consistent with sensory integration. Broadly, these studies can be grouped into four categories: interventions that utilize touch (i.e., massage or touch therapy); interventions that utilize weighted vests; auditory interventions; and other interventions (the Wilbarger Protocol, therapy balls, and sensory diet). Again, the majority of the studies utilized case study, SSED, or group design protocols and are limited by small sample sizes and other methodological flaws. Thus, it is difficult to draw practice implications.

Touch-Based Treatments

The four studies summarized in Table 9.3 utilize massage, touch therapy, or deep pressure stimulation.

Escalona et al. (2001) examined whether nightly massage improved the sleeping habits and behaviors of children with autism. Twenty subjects with autism between the ages of 3 and 6 years of age were randomly assigned to either a control group or a massage therapy group. Parents were trained in the massage therapy and provided it every night for 15 min prior to bedtime for 1 month. Control subjects were read a story for 15 min by parents. Outcome measures were the Revised Conners Scales (Conners 1997) and observation of classroom behaviors (pre- and post-intervention). Parents also kept sleep diaries. The treatment group showed improvements on the Conners Scale ($p < 0.05$) and in observation measures of play behaviors including a greater decrease in stereotypical behaviors ($t = 2.01$, $p < 0.05$) and a greater increase in on-task behavior ($t = 2.13$, $p < 0.05$), and better sleeping patterns as evidenced by more time spent in deep sleep and less night waking. The latter results do not report statistical significance.

Field et al. (1997) examined the effects of touch therapy on inattention, touch aversion, and withdrawal in 22 children

with autism who had an average age of 4.5 years. Subjects were randomly assigned to either touch therapy or control. Touch therapy consisted of 15 min of touch in the form of moderate pressure and smooth strokes along the entire body. Children were assessed on the first and last day of intervention using the Autism Behavior Checklist (Krug et al. 1993) and the Early Social Communication Scales (Seibert et al. 1982). Touch aversion, off-task behavior, and orientating to irrelevant stimuli decreased in both groups although significantly ($p < 0.05$) more in the treatment group. Only children in the touch-therapy group showed decreased scores on the sensory scale and the Autism Behavior Checklist. Children in the treatment group also showed significant ($p < 0.05$) changes on the Early Social Communication Scales in the area of joint attention ($p < 0.05$), behavioral regulation ($p < 0.01$), social behavior ($p < 0.05$), and initiating behavior ($p < 0.01$).

Silva et al. (2009) completed a multi-site, randomized control trial of massage, using a specific type of massage, Qigong Massage. They conducted a randomized controlled study of 46 children diagnosed with ASD and measured the effects of the treatment (Qigong massage) on adaptive behavior, sensory symptoms, digestion and sleep (all evaluated by parent and teacher report). Teacher report (blinded) showed that treated children had significant improvements in the language and social skills domains of the Vineland ($p < 0.01$) and reduction in autistic behaviors ($p < 0.03$) compared to controls. Parent data confirmed the findings and showed stability of results at 10 months. This study is strong methodologically as subjects were randomly assigned, interventionists were trained, and data were collected pre-treatment, post-treatment, and at 5 months following intervention; it thus provides emerging evidence for the use of Qigong Massage on the stated outcomes.

TABLE 9.3 Studies of touch-based treatments

Study	Participants	Outcome	Evidence-based rating	Quality indicators present
Escalona et al. 2001	N=20 children aged 3-6 years with ASD	Dependent Variables: off-task behavior and sleep problems via the Conner's Scale and teachers' observations. <i>Results:</i> children who received massage therapy showed increases in on-task behavior, attentiveness and better sleeping patterns	Adequate	<ul style="list-style-type: none"> Primary: independent variable, comparison condition exists but does not specifically indicate what it was, dependent variable, use of statistical tests Secondary: random assignment
Field et al. 1997	N=22 children (12 male, 10 female) average age of 4.5 years with ASD	Touch aversion, off-task behavior, orienting to irrelevant sounds, and stereotypic behaviors decreased in both groups (orienting to irrelevant sounds and stereotypic behaviors decreased significantly more in the touch therapy group). Only children in the touch therapy group showed decreased scores on the sensory scale, relating scale, and the total scores of the ABC. Children in the touch therapy group showed significant changes in joint attention, behavior regulation, social behavior, and initiating behavior.	Strong	<ul style="list-style-type: none"> Primary: participant information, independent variable, comparison condition, dependent variable, use of statistical tests, link better research question and data analysis Secondary: random assignment
Silva et al. 2009	N=26 children aged 3-6 years with an educational diagnosis of autism but no additional medical diagnoses	Pre-test to post-test differences on standardized measures (adaptive behavior, sensory impairment and autistic behavior) were all found to be statistically significant at .003 level or better. Trainers and parents were able to administer intervention in a reliable manner.	Strong	<ul style="list-style-type: none"> Primary: participant information, independent variable, dependent variable, use of statistical tests (pre-post test differences on objective, standardized measures), link research question, and data analysis Secondary: fidelity rating, social validity
Edelson et al. 1999	N=12 children (nine male, three female) aged 4-13 years with a physician diagnosis of autism	Experimental group showed non-significant decreases in anxiety and tension after treatment; control group did not. Greater arousal (measured by galvanic skin response) may predict greater efficacy of deep pressure.	Weak	<ul style="list-style-type: none"> Weakness: No comparison group, pre-post design Primary: participant characteristics, independent variable, comparison condition, dependent variable, use of statistical tests Secondary: random assignment

Edelson et al. (1999) reported a study of the effects of deep pressure on arousal and anxiety. The study used the Grandin hug machine (Grandin 1992), a device that allows for self-administration of lateral body pressure. Twelve subjects (nine males and three females ranging from 4 to 13 years of age) with a physician diagnosis of autism participated but there was no detail of the methods used for diagnosis. Five subjects were in the experimental condition and subjects were matched on age and gender. Prior to administration of treatment, both groups showed statistically similar levels of arousal and anxiety. Outcome measures were galvanic skin response (GSR) measured before and immediately after each session, the Conners' parent rating scale (Goyette et al. 1978), and a side effects questionnaire to measure any side effects of the deep pressure. Data from the Conners' scale was assessed using a 2×3 (group \times time) MANOVA (pre-, mid-, and post-session time points) and showed that the tension and anxiety decreased in the experimental group ($p < 0.05$ and $p < 0.10$ respectively). Results of GSR are difficult to evaluate as they rely on demonstrating that physiological and behavioral measures converged prior to treatment and remain highly correlated with each other throughout the study. Further, in evaluating changes in GSR between the groups, there were non-significant differences but the authors did note that variability in GSR increased in the treatment group and decreased in the control group. They felt that this observation suggested that individuals within the treatment group responded differently to the intervention and thus, divided them into responders or non-responders based on their initial levels of anxiety or arousal. They found a marginally significant difference between those who benefited and those who did not – those who benefited were more likely to have higher GSR – but the sample sizes for this analysis are very small. They

suggest that greater arousal may predict greater efficacy of deep pressure. This study is weak in that many of the study characteristics were not described (participant characteristics, inter-rater reliability) and random assignment was not detailed. The study did identify the independent and dependent variables, describe the comparison condition, and statistical tests, but findings were weak and liberties were taken in the interpretation of the findings.

Collectively, the studies using touch as the intervention show encouraging evidence in that improvements in target behaviors are noted. In general, the studies describe an intervention that can be replicated, describe the subject characteristics in detail, and utilize accepted statistical procedures in the data analysis and interpretation. Drawing strong conclusions from this data is limited, however, by the variability in intervention (touch pressure vs. massage) and the lack of an active control group or fidelity measure.

Interventions That Utilize Weighted Vests

Six studies, shown in Table 9.4, examined the effect of using weighted vests in children with ASD on attention, self-stimulatory behaviors, or on-task behaviors. One confounding factor in interpretation of these studies is that the weighted vest, although it provides mainly proprioception (the weight of the vest requires that increased muscle activity be utilized and thus increases the proprioceptive signals from the muscles, joints and tendons) may also provide some amount of pressure touch (due to the vest being placed on the torso) and thus, it is difficult to determine the nature of the stimuli that is being studied.

Fertel-Daly et al. (2001) examined the effects of weighted vests on five subjects with PDD (aged 2–4 years old) using an

TABLE 9.4 Studies of weighted vest treatments

Study	Participants	Outcome	Evidence-based rating	Quality indicators present
Fertel-Daly et al. 2001	N = 5 children aged 2-4 diagnosed with PDD; one also with autism	During intervention, focused attention to task increased; during intervention withdrawal, it decreased but stayed above the baseline level. During intervention, the number of distractions decreased; during intervention withdrawal, it increased but stayed below the baseline level. During intervention, four participants showed a decrease in the duration of self-stimulatory behaviors and one showed an increase. During intervention withdrawal, self-stimulatory behaviors increased. Parent and teacher behavioral reports were all positive for children who received intervention with weighted vests and reported gains in areas not directly tested by this study.	Adequate	<ul style="list-style-type: none"> Primary: participant characteristics, independent variable, dependent variable, link between research question and data analysis Secondary: inter-observer agreement, social validity
Kane et al. 2004-05	N = 4; three subjects with autism and one participant with PDD A-B-C design: no vest, vest with no weight, weighted vest	No significant improvements in attention or decreases in stereotypic behaviors with the use of a weighted vest.	Adequate	<ul style="list-style-type: none"> Primary: participant characteristics, independent variable, dependent variable, link between research question and data analysis Secondary quality indicator: social validity Weakness: no interobserver agreement assessed
Olson and Moulton 2004	N = 514 pediatric occupational therapists	The majority of weighted vests used support therapeutic and occupational goals. Protocols for using weighted vests varied and were difficult to follow, although the majority of respondents (73%) recommended wearing the vest for less than 1 h each time.	Not applicable	Evidence-based rating is not applicable as this is a survey of occupational therapists' perspectives on the use of weighted vests.

Stephenson and Carter 2009	Subjects described in the individual studies	Four articles claimed the weighted vests proved ineffective in reducing problem behaviors. One article produced mixed results. Two articles claimed the weighted vests proved effective in reducing problem behaviors.	Not applicable	Evidence-based rating is not applicable as this is a review of current research.
Cox et al. 2009	N=3 subjects of elementary school age, with a diagnosis of autism and intellectual disability and sensory processing abnormalities (as measured by the Short Sensory Profile)	The weighted vest did not have an effect on in-seat behavior. The behavioral intervention (noncontingent reinforcement) improved in-seat behavior.	Adequate	<ul style="list-style-type: none"> • Primary: participant characteristics, independent variable, dependent variable, link between research question and data analysis • Secondary: social validity strong, interobserver agreement assessed • Weakness: single subject case study, autism diagnosis was made using different assessments at varied locations, assessment of sensory processing inadequate
Reichow et al. in press	N=3 subjects, ages 2-6 years, with an educational or medical diagnosis of autism or developmental delay	For one subject, there was an increase in problematic behaviors when wearing the vest and a decrease in stereotypic behaviors. There were no differences for the other two subjects in any of the observed behaviors among the three conditions.	Strong	<ul style="list-style-type: none"> • Primary: participant characteristics, independent variable, comparison condition, dependent variable, link between research question and data analysis, use of statistical tests • Secondary: random assignment, inter-rater agreement, social validity

A-B-A withdrawal single subject study. Observations of focused attention to task, number of distractions, and duration and type of self-stimulatory behaviors during a 5-min fine motor activity were collected and plotted for visual analysis. Data for the intervention began in the third week of the study. The intervention consisted of wearing the weighted vest (four quarter-pound weights) three times per week for 2 weeks. Vests were worn for 2 h as soon as the child arrived at school and data were collected after 1.5 h of wearing the vest. Intervention was discontinued in the fifth week of the study and data were collected for two additional weeks. Results compared mean duration of focused attention, number of distractions, and duration of self-stimulatory behavior during each phase of the study. The authors concluded through visual analysis that all subjects' data "supports the clinical observation that a weighted vest had a positive effect on at least two measures of attention for all five participants" (Fertel-Daly et al. 2001, page 638). An additional finding was that the increase in focused attention that occurred during the intervention was not sustained when the vest was removed and four participants had an abrupt drop in the duration of focused attention to task. The article concluded that a weighted vest "appeared to be beneficial... for five children with PDD who had difficulty attending to tasks and who exhibited self-stimulatory behaviors."

Kane et al. (2004-05) conducted a single subject study with an A-B-C (no vest, vest with no weight, weighted vest) counterbalanced design with three subjects with autism and one participant with PDD using a vest specifically made for the study that was 5% of the child's weight. The findings indicated no significant improvements in attention or decreases in stereotypic behaviors with the use of a weighted vest and the authors conclude that their study does not support the use of a weighted vest to decrease stereotypic behaviors or improve

attention. The study design was single subject and thus the generality of these findings is limited. In addition, the study is flawed in that inter-observer agreement was not assessed. It is difficult to assess if findings are specifically related to the weight of the vest or to other qualities of the study (the vest was noted to be distracting to some subjects, activities provided to evaluate attention were not counterbalanced), nonetheless, this study is methodologically strong in its adherence and use of the single subject A-B-C design.

Reichow et al. (in press) completed a study of three subjects (aged 2-6 years), with an educational or medical diagnosis of autism or developmental delay, to determine if wearing a weighted vest increased engagement during a table-top activity. The vest was 5% of the child's weight. This study was methodologically strong in that it utilized an alternating treatments design with three conditions (vest with weight, vest with no weight, and no vest), controlled for the vest-with-no-weight condition to ensure that there were no visually perceived differences between this and the weighted-vest conditions and thus the observers were blind to the study condition, and the conditions were randomly assigned based on a 5-day schedule (for example, one child might have 2 days with no vest, then 2 days with a vest and 1 day without the vest whereas another subject might have a different schedule). Videotape recordings of behavior during table-top activities were utilized and raters coded for engagement, non-engagement, stereotypic behaviors, and problem behaviors. Each behavior was defined. Interobserver agreement was excellent (0.93-0.96). Findings are reported by subject. For one subject there was an increase in problematic behaviors when wearing the vest and a decrease in stereotypic behaviors. There were no differences for the other two subjects in any of the observed behaviors among the three conditions. Findings do

not provide any evidence of positive gain from the vest and suggested the possibility of negative outcomes (i.e., decreased engagement). This study provides emerging evidence that weighted vests are not effective for improving engagement during table-top activities. The quality of the study is high given the attention to methodological issues stated above, however, the ability to generalize is limited by the SSED methodology and would be strengthened by including a greater number of sessions. The observers were graduate students and it is not clear if they were blind to the opinions of the other members of the research team. The social validity of the study is high in that it is an area of high interest for teacher, clinicians, and families.

Cox et al. (2009) examined the effects of a weighted vest, a vest with no weights and no vest on in-seat behavior during a group activity on three elementary-age students with autism, intellectual disabilities, and sensory processing difficulties. This study was methodologically strong as it used an alternating treatments design to compare the effects of the three conditions – the three conditions are randomly and rapidly alternated and counterbalanced across participants to control for sequence effects – and then utilized a generalization condition to determine if effects would generalize to a different group activity. In-seat behavior was defined and evaluated by viewing videotapes of observed behaviors in 10-s intervals. Interobserver agreement on occurrence (94.7% average agreement) and nonoccurrence ratings of behaviors (88.2% average agreement) was good. The percentage of intervals for appropriate in-seat behavior was visually displayed for baseline and each condition and the percentage overlap between conditions was calculated by counting the number of data points in the second condition that fall within the range of the first condition and then multiplying by 100. High percentages of overlap were found and, thus,

the authors concluded that the weighted vest did not have an effect on appropriate in-seat behavior for the participants. A second experiment was conducted to evaluate whether a behaviorally based intervention (noncontingent reinforcement, where subjects were given the choice of two highly preferred objects that they were allowed to access during the group activity) had an effect on in-seat behavior. Findings indicated that this strategy did improve in-seat behavior in the subjects. The authors concluded that, for these participants, the behavioral intervention had a stronger effect on in-seat behavior than the sensory intervention even though participants were identified as having sensory processing abnormalities.

This study is limited by the use of single subject methodology and thus the findings cannot be generalized. Another limitation is that the subjects were diagnosed with autism using different assessments and at different institutions. In addition, in-seat behavior was scored based on the subjects remaining in their seat for a full 10 s, which may limit the ability to detect changes that occur in smaller time increments. Finally, the study suggests that they were evaluating the effects of “sensory integration” whereas they are studying the effects of one sensory modality; they suggest that the study evaluates “deep pressure” on in-seat behavior, although it is difficult to determine if deep pressure (from the tightness of the vest) was provided at all or if the major sensory system stimulated was proprioception (as is generally the case with a weighted vest). This is important because it points to confusion about the use of sensory integration as opposed to sensory-based (single sensory system) strategies and the need to tailor treatment strategies to the individual needs of the child. For example, based on the information provided, it is impossible to evaluate whether the choice of the weighted vest was made based on the subjects scoring deficient in

proprioceptive processing or some other criteria. Of note, only one subject scored in the "definite difference" range on tactile sensitivity and there is no information about proprioceptive processing. This issue speaks to the importance of individually tailoring sensory-based interventions to the child's specific needs rather than utilizing a strategy for all subjects universally. Further, this issue speaks to the importance of a comprehensive assessment of the child's ability to process and integrate sensory information that includes not only a measure of sensory modulation (as in the Short Sensory Profile) but a more comprehensive assessment of processing and integration of sensation and its effects on praxis and behavior.

Of the remaining two reports on weighted vests used with an ASD population, one article was a review of existing studies (Stephenson and Carter 2009) and another was a survey of therapists (members of the School-Based Special Interest Section or the Sensory Integration Special Interest Section of the American Occupational Therapy Association, AOTA) to determine their protocols and clinical reasoning for using weighted vests (Olson and Moulton 2004). These two reviews are shown in Table 9.4 but not elaborated on here.

Overall, the use of weighted vests to improve attention and self-stimulating behaviors is difficult to evaluate as few studies were found for children with ASD and they were conducted using SSED.

Auditory Interventions

Four studies, shown in Table 9.5, report on auditory interventions with children with ASD. Conclusions from this group of studies are difficult because they utilize different types of auditory intervention with varying levels of rigor, however, there is a trend that auditory interventions do not

demonstrate any notable improvements in behaviors over either no treatment or a control condition of auditory input.

Mudford et al. (2000) reported a cross-over experimental design study of 16 children with autism using an auditory integration training developed by Berard (1993). The intervention program involved playing modified music through headphones for 30-min sessions twice a day for 10 days whereas the control condition played music in the room but not through the training device or headphones. The study is promising in that participants were adequately described (ages 5.7–13.9 years with an average age of 9.42); the diagnosis of autism was confirmed based on the *International Classification of Diseases and Related Health Problems*, 10th edition (ICD-10; World Health Organization 1992) and DSM-IV (APA 1994) classifications; and measures of cognitive abilities and adaptive behavior were used. Dependent variables were the Aberrant Behavior Checklist (Aman et al. 1996) and direct observational recordings of behavior for an average of 3.82 h across the 14 months of the study. They reported seven statistically significant effects from 32 dependent variables, but none of the effects favored the auditory intervention. For example, they found that parent-rated behaviors on the Aberrant behavior checklist decreased more following the control condition compared to the auditory training intervention (Wilcoxon $z=1.91$, $p=0.06$, two-tailed) and that ear occlusion increased after the auditory intervention ($p = 0.03$). Overall IQ scores on the Leiter did not increase significantly (decreased from 68 to 66) and Vineland Adaptive Behavior Composite scores decreased but not significantly. The authors concluded that the control condition was more beneficial than the auditory integration training.

Corbett et al. (2008) reported a study designed to test the effects of the Tomatis Method on language skills. Eleven subjects

TABLE 9.5 Studies of auditory interventions

Study	Participants	Outcome	Evidence-based rating	Quality indicators present
Bettison 1996	N = 80 children (66 male and 14 female) Aged 3.9–17.1 years, with a primary diagnosis from an independent agency of autism, significant autism symptoms, or Asperger syndrome	There were marked improvements in the behavioral measures for both groups at 1 month but there was a general lack of differences between the groups.	Strong	<i>Primary:</i> participant characteristics, independent variable, comparison condition, dependent variable, power analysis, and use of statistical tests <i>Secondary:</i> random assignment, inter-rater agreement, social validity
Mudford et al. 2000	N = 16 children (17 male, 4 female)	ABC scores were lower following control treatment than AIT.	Adequate	<i>Primary:</i> Participant characteristics, independent variable, comparison condition, dependent variable, use of statistical tests <i>Secondary:</i> random assignment, blind raters
Sinha et al. 2006	Aged 5.75–13.92 years, with a diagnosis of autism Subjects described in the individual studies	Much of the change in behavior was not statistically significant. Overall, researchers state no behavioral benefits from AIT therapy. Two studies did not find consistent improvement in behavior. Three trials found small improvements when groups were compared to control. Measures of cognitive ability and hearing sensitivity did not differ when compared between groups.	Not applicable	Evidence-based rating is not applicable as this is a review of current research
Corbett et al. 2008	N = 11 children (9 male and 2 female) Aged between 3.5 and 7.2 years, with autism	No significant difference found between treatment and placebo groups on language tests. All subjects showed progression in verbal reception over the course of the study; however, this progression did not correlate with the administration of Tomatis Sound Therapy.	Strong	

with autism (based on DSM-IV criteria (APA 1994)), which was corroborated by the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2002) and clinical judgment. Subjects were aged 3.5–7.2 years; nine subjects were male and two were female. Outcomes were measured using the ADOS, the Stanford-Binet intelligence scale (Thorndike et al. 1986), the Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn 1997), and the expressive one-word picture vocabulary test (Brownell 2000). They use a randomized, double-blind, placebo-controlled crossover design. Tomatis training was administered by trained assistants and researchers and parents were blind to condition. In keeping with the Tomatis Method, the combination of filtered music listened to through an "electronic ear" headphones and auditory feedback should result in enhanced auditory perception. However, no significant difference was found between treatment and control groups on the PPVT or the Expressive one-word picture vocabulary test and, thus, the authors concluded that their results do not provide evidence for the treatment.

Bettison (1996) reported a study of the long-term effects of auditory training on 80 children (66 males and 14 female), aged 3.9–17.1 years. All children had a primary diagnosis of autism, significant autism symptoms, or Asperger syndrome from an independent agency (no further information on autism diagnosis was provided). There were no differences between the groups on age, sex, or educational program attended. Auditory training followed the Berard (1993) method, which involved listening to filtered music on 16 CDs (up to 14 frequencies). The control group received structured listening to unmodified music under the same conditions as the treatment group (two half-hour sessions at least 4 h apart each day for 10 consecutive days). Measures included the Autism Behavior Checklist (ABC) (Krug et al. 1993), the Developmental behavior checklist (DBC),

parent and teacher (Brereton et al. 2002), subtests from the PPVT (Dunn and Dunn 1981), and the Leiter international performance scale (Roid and Miller 1997). Sensory behaviors were assessed using the sensory problems checklist and the sound sensitivity questionnaire (SSQ; Rimland and Edelson 1994). Scores on each child's audiogram were also assessed pre- and post-intervention. Inter-rater reliability was established for each measure and ranged from 0.90 to 0.99. *T*-tests to compare pre- and post-test scores were conducted at 1, 3, 6, and 12 months after intervention. Overall, there were marked improvements in the behavioral measures for both groups at 1 month, but there was a general lack of statistically significant differences between the groups. The authors suggested that the lack of difference between the groups suggests that, "some aspect of both conditions was operating to cause these changes" (Bettison 1996, p. 370). Of interest, the IQ scores as measured by the Leiter improved in both groups, however, the magnitude of improvement was greater for the intervention group. The authors felt that this may suggest an intervention effect on IQ score although they also noted that practice obtained during intervention cannot be ruled out as a factor influencing this finding. For example, for the ABC, statistically significant improvements were found at 1 month and these were maintained through 6 months but reverted to levels at 1 month when tested at 12 months. The main finding from this study is that both the auditory training and the structured listening may lead to reductions in auditory sensitivities but that further research is needed to confirm this finding. This study is strong in that it contains several primary quality indicators: participant characteristics are described, independent variable, intervention and comparison condition, and dependent variable are described, and the link between research question and data analysis is clear. The use of statistical tests is appropriate and

several secondary quality indicators are present including random assignment and inter-rater agreement. The social validity is high in that the research addresses a question that is of high interest in the field.

Other Sensory Techniques

In this section, we consider three studies that each examined one specific other intervention (the Wilbarger Protocol, therapy balls, and sensory diet). They are summarized in Table 9.6.

Kimball et al. (2007) conducted a study to evaluate the Wilbarger protocol, which provides "very deep pressure input to the skin with a specially manufactured non-scratching brush followed by compression of the major joints" (Wilbarger and Wilbarger 2001, p. 406). They evaluated changes in salivary cortisol after 4 weeks of treatment. The protocol is designed to be administered every 1.5–2 h but it was administered only once per week in the morning so as to keep with the routine of the subjects. The study used a single subject A–B design with a convenience sample of four boys (aged 3–5 years) showing signs of sensory defensiveness as indicated by their primary occupational therapist. Sensory defensiveness was confirmed using the short sensory profile but no cut-off scores were mentioned. They also administered the Conners' Rating Scale (Conners 1997) to examine correlates of behavioral issues pre- and post-intervention. Although all children's salivary cortisol levels moved in the direction expected after application of the Wilbarger-based protocol, no statistical significance is reported. This study is very weak in that it lacked adequate subject descriptions, failed to report statistical significance, the protocol was not carried out in the way intended, the link between research question and data analysis was not clear and there was no mention of inter-rater agreement. The social validity is high

in that the research addresses a question that is of high interest in the field.

Schilling and Schwartz (2004) conducted a study to evaluate the use of therapy balls used as a seating alternative for young children with ASD on engagement and in-seat behavior. Four male subjects (aged from 3 years 11 months to 4 years 2 months) participated in a withdrawal SSED. Each subject had a physician diagnosis of ASD but no further detail about the diagnostic criteria was mentioned. Each participant's characteristics were described in detail and participants were selected for the study based on teacher reports of difficulty with engagement and in-seat behavior and the intervention was individualized based on each participant's situation (e.g., participant 1 received intervention during art activities in his extended day program and, since the length of time for each art activity varied, the data collection varied from 5 to 10 min). Data on dependent variables (sitting and engagement) were collected via real time sampling and interobserver agreement ranged from 82% to 100%. Intervention (use of therapy ball for classroom sitting during an individually chosen activity) was implemented for a minimum of 2 weeks. Three of the four participants showed immediate and substantial improvements for in-seat behavior with the implementation of therapy balls. These three individuals also showed a marked return to baseline levels upon withdrawal. This study is strong in that primary quality indicators such as independent variable, dependent variable, description of participants, and adherence to study design are evident as is the link between research question and data analysis. Social validity is directly addressed in the design of the study and data on social validity is collected via staff questionnaire.

Ingersoll et al. (2003) studied the effects of sensory feedback on immediate object imitation for children with ASD. Sensory feedback was achieved through the use of toys with flashing lights and sound. The

TABLE 9.6 Studies of other sensory techniques

Technique	Study	Participants	Outcome	Evidence-based rating	Quality indicators present
Wilbarger protocol	Kimball et al. 2007	N = 4 boys (receiving services at the Community Occupational Therapy Clinic, University of New England) aged 3-5 years, two with PDD or autism; all showed signs of sensory defensiveness, according to their primary occupational therapist	Although all children's salivary cortisol levels moved in the direction expected after application of the Wilbarger-based protocol, there is no statistical significance reported.	Weak	<i>Primary:</i> dependent variable <i>Secondary:</i> social validity
Therapy balls	Schilling and Schwartz 2004	N = 4 male children aged 3;11-4;2, with a physician diagnosis of ASD and reported by teachers as having trouble with in-seat behavior and difficulty with task engagement.	Three of the participants showed immediate and substantial improvements in in-seat behavior with the implementation of therapy balls. These individuals also showed a marked return to baseline levels upon withdrawal.	Strong	<i>Primary:</i> participant characteristics, independent variable, dependent variable, link between research question and data analysis <i>Secondary:</i> inter-observer agreement, social validity
Sensory feedback	Ingersoll et al. 2003	N = 15 children (nine boys, six girls) with autism and 14 children (five boys, nine girls) developing typically ages ranged from 23 to 53 months	Although overall imitation performance did not differ significantly between the two groups, the imitation performance of the participants with autism was significantly higher with sensory toys than with no sensory toys. Both groups played significantly more with the sensory toys during free play, suggesting that sensory toys were more reinforcing for both groups. It is argued that children with autism may be less motivated to imitate by social interaction but may be motivated to imitate to receive a nonsocial reward (sensory feedback).	Weak	<i>Primary:</i> participant characteristics, independent variable, dependent variable <i>Secondary:</i> social validity

subjects were 15 children (nine boys and six girls) with ASD and 14 typically developing children (five boys and nine girls). Subjects with ASD were previously diagnosed and confirmed by the study author. Participants ranged in age from 23 to 53 months and there were no differences between the groups on mental age. The experiment compared imitation using toys that had sensory feedback versus the same toy with no sensory feedback using the motor imitation scale (Stone et al. 1997). Analysis used mixed-model repeated measures ANOVA and although overall imitation performance did not differ significantly between the two groups, the imitation performance of the participants with autism was significantly higher with sensory toys than with non-sensory toys ($p < 0.02$). The imitation performance of typically developing participants did not differ between the two sets of toys and both groups played significantly more with the sensory toys during free play, indicating that the sensory toys were more reinforcing for both groups. Additional results demonstrated that typical children used significantly more social behaviors during imitation than children with autism, but they did not differ in object-oriented behaviors, replicating previous findings. It is argued that children with autism may be less motivated to imitate by social interaction, but may be motivated to imitate to receive a nonsocial reward (sensory feedback). Although inter-rater reliability was calculated (it ranged from 0.71 to 0.95) and the experimental conditions were clearly described, the diagnosis of autism was not confirmed, and the study did not report on a number of other primary and secondary quality indicators.

CONCLUSION

Overall, the data supporting the sensory-integrative approach is promising, whereas the data related to isolated sensory

strategies is problematic. Several factors have limited the conduct of rigorously controlled studies of the sensory integration approach, including lack of a specific intervention protocol, the absence of a fidelity measure, and the paucity of meaningful outcome measures that are in keeping with the theoretical principles of the intervention and that describe changes at the levels of activity and participation as recommended by the World Health Organization (2001). These issues were discussed in the introductory section of this chapter, as were the efforts that are underway to fill these voids and lay the foundation for rigorous controlled studies. However, from the findings of the majority of studies that investigated the sensory-integrative approach, it is felt that there is emerging evidence to support the use of the sensory-integrative approach for individuals with ASD, in particular to impact sensory and motor outcomes and individual client-centered goals.

Overall, the studies of other sensory techniques, with the exception of Qigong Massage, do not establish the techniques as evidence-based and they should be regarded as still in the experimental stages. The strongest support comes from the group of studies using touch-based intervention; however, given that each study used different interventions, it is not possible to draw strong conclusions. Thus, touch-based interventions should also be used cautiously. In general, interventions that use isolated sensory techniques should be recommended cautiously and, when used, systematic data should be collected and analyzed frequently to assess utility. Given that many children with ASD are receiving treatment for their SD to help deal with behavioral issues and sensory sensitivities and parents and funding agencies are spending a great deal of money and time on these, the need for solid research has reached a critical level.

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- Ayres Sensory Integration was trademarked in an effort to clarify the concepts that reflect Ayres's sensory integration framework and to distinguish it from other sensory approaches that do not use Ayres work in the way it was intended (Smith Roley and Mailloux 2007)