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Review

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A systematic review of sensory processing interventions for children with autism spectrum disorders

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Abstract

Children with autism spectrum disorders often exhibit co-occurring sensory processing problems and receive interventions that target self-regulation. In current practice, sensory interventions apply different theoretic constructs, focus on different goals, use a variety of sensory modalities, and involve markedly disparate procedures. Previous reviews examined the effects of sensory interventions without acknowledging these inconsistencies. This systematic review examined the research evidence (2000–2012) of two forms of sensory interventions, sensory integration therapy and sensory-based intervention, for children with autism spectrum disorders and concurrent sensory processing problems. A total of 19 studies were reviewed: 5 examined the effects of sensory integration therapy and 14 sensory-based intervention. The studies defined sensory integration therapies as clinic-based interventions that use sensory-rich, child-directed activities to improve a child's adaptive responses to sensory experiences. Two randomized controlled trials found positive effects for sensory integration therapy on child performance using Goal Attainment Scaling (effect sizes ranging from .72 to 1.62); other studies (Levels III–IV) found positive effects on reducing behaviors linked to sensory problems. Sensory-based interventions are characterized as classroom-based interventions that use single-sensory strategies, for example, weighted vests or therapy balls, to influence a child's state of arousal. Few positive effects were found in sensory-based intervention studies. Studies of sensory-based interventions suggest that they may not be effective; however, they did not follow recommended protocols or target sensory processing problems. Although small randomized controlled trials resulted in positive effects for sensory integration therapies, additional rigorous trials using manualized protocols for sensory integration therapy are needed to evaluate effects for children with autism spectrum disorders and sensory processing problems.

Keywords

sensory integration therapy, sensory processing, systematic review

Current estimates indicate that more than 80% of children with autism spectrum disorders (ASD) exhibit co-occurring sensory processing problems (Ben-Sasson et al., 2009), and hyper- or hyporeactivity to sensory input is now a diagnostic criterion for ASD in the *Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition* (*DSM-5*; American Psychiatric Association, 2013). Children who exhibit sensory hyperreactivity may respond negatively to common sensory stimuli, including sounds, touch, or movement. Their responses include distress, avoidance, and hypervigilance (Mazurek et al., 2012; Reynolds and Lane, 2008). Children who are hyporeactive appear unaware or nonresponsive to sensory stimuli that are salient to others (Miller et al., 2007a). A subgroup of children who are hyporeactive exhibit sensory-seeking behaviors (i.e. they appear to seek intense stimulation to increase their arousal) that may manifest as restricted, repetitive patterns of behavior (Ornitz, 1974; Schaaf et al., 2011).

Historically, Kanner (1943) documented that children with ASD had sensory fascinations with light and spinning objects and oversensitivity to sounds and moving objects (p. 245). More recently, researchers have documented that children with ASD seek or avoid ordinary auditory, tactile, or vestibular input (Baranek et al., 2006; Ben-Sasson et al.,

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2009; Rogers and Ozonoff, 2005), suggesting impairment in sensory modulation across systems (Dahlgren and Gillberg, 1989). Specific sensory modulation problems reported by people with ASD (e.g. Grandin, 1992; Williams, 1995) include hyperreactivity to touch or sounds, hyporeactivity to auditory input, and unusual sensory interests. The most common type of sensory modulation problem in ASD appears to be hyporeactivity, particularly in social contexts (Baranek et al., 2006). A meta-analysis of sensory modulation symptoms in ASD found that effect sizes for the differences between children with and without ASD were greatest for hyporeactivity ($d = 2.02$) but also notable for hyperreactivity ($d = 1.28$) and sensory-seeking ($d = .83$) (Ben-Sasson et al., 2009). Although sensory processing problems appear to be greater in childhood (Ben-Sasson et al., 2009), they are self-reported to be lifelong (Grandin, 1995).

Sensory processing problems in ASD are believed to be an underlying factor related to behavioral and/or functional performance problems. Ornitz (1974) hypothesized that sensory modulation problems are related to the stereotypic or repetitive behaviors displayed by children with ASD, and that the stereotypic behaviors reflect the child's attempt to lower arousal (self-calm) or increase arousal (sensory-seeking). Researchers have attributed repetitive movements, such as rocking, twirling, or spinning behaviors, to sensory processing problems (Ornitz et al., 1978; Rogers et al., 2003; Schaaf et al., 2011). Joosten and Bundy (2010) found that a sample of children with ASD and stereotypical behaviors had significantly greater sensory processing problems ($d = 2.0$) than do typical children. Rigid behaviors (e.g. refusing to transition to a new activity, preferring a rigid routine) or preference for sameness may also be motivated by hyper- or hyporeactivity (Lane et al., 2010).

Sensory processing problems in ASD may also influence a child's functional performance in daily activities, such as eating, sleeping, and daily routines, including bath time and bedtime behaviors (Schaaf et al., 2011). Children with selective eating often have olfactory and/or gustatory oversensitivities that can cause aversion to certain foods (Leekam et al., 2007; Paterson and Peck, 2011). Hyperreactivity or aversion to tastes or smells can lead to anxiety or rigidity about eating and these states can evolve into disruptive and stress-producing behaviors at mealtime (Cermak et al., 2010). Sensory processing problems can also disrupt children's sleeping patterns; Reynolds et al. (2012) found that children with ASD and sensory modulation problems have poor sleeping patterns, specifically have difficulty falling asleep, and that these problems appear to relate to sensory modulation. Between 50% and 80% of children with ASD have sleeping difficulties (Richdale and Schreck, 2009) that seem to relate, at least in part, to sensory processing problems (Klintwall et al., 2011; Reynolds and Malow, 2011).

Sensory processing problems have also been linked to anxiety in children with ASD. Green and Ben-Sasson (2010) proposed a model to explain how hyperreactivity in children with ASD can be characterized as hyper-attention to sensory stimuli and overreaction to those stimuli. Hyperreactivity can lead to overarousal, difficulty regulating negative emotion, and avoidance or negative responses to everyday sensory stimuli. Over time, poor regulation of arousal may result in anxiety (Bellini, 2006) and may be particularly stressful for the nonverbal child who lacks communication skills to express his or her anxiety (Green and Ben-Sasson, 2010). In a large sample of children with ASD and gastrointestinal problems, sensory hyperreactivity correlated with anxiety levels, and hyperreactivity and anxiety uniquely contributed to gastrointestinal symptoms (Mazurek et al., 2012).

Although studies have demonstrated that sensory processing problems can influence the behavior of children with ASD, the relationships among sensory-driven behaviors, arousal, self-regulation, attention, activity levels, and stereotypic behaviors are not well understood. When sensory processing problems are believed to influence a child's behavior, interventions that use sensory modalities to support self-regulation, promote optimal arousal, improve behavioral organization, and lower overreactivity are often recommended.

Interventions for sensory processing disorders

Despite wide recognition of sensory processing problems and their effects on life participation for individuals with ASD, sensory interventions have been inconsistently defined and refer to widely varied practices. As found in the literature and in practice, sensory interventions use a variety of sensory modalities (e.g. vestibular, somatosensory, and auditory), target behaviors that may or may not be associated with sensory processing disorder, involve a continuum of passive to active child participation, and are applied in different contexts. These interventions arise from different conceptualizations about sensory integration and sensory processing as neurological and physiological functions that influence behavior. Furthermore, they use a variety of methods (e.g. sensory integration therapy (SIT) (Ayres, 1972), massage (Field et al., 1997), and auditory integration training (Bettison, 1996)). This variation in sensory interventions combined with inconsistent use of terminology has resulted in considerable confusion for parents, practitioners, and researchers. With disparate and sometimes conflicting rationale for using sensory interventions for ASD, researchers have hypothesized that they can inhibit stereotypical behaviors (e.g. Davis et al., 2011), reduce self-injurious behaviors (e.g. Devlin et al., 2009; Smith, et al. 2005), improve attention to task (e.g. Watling and Dietz, 2007), increase sitting time (e.g. Hodgetts et al., 2010; Schilling and Schwartz, 2004), elicit adaptive responses (Schaaf et al., 2013), and improve sensory motor performance (Fazlioglu and Baran, 2008). Although researchers have applied sensory interventions to improve behaviors hypothesized to reflect self-regulation, most studies did not use neurophysiological measures and many did not include sensory processing measures (e.g. Bonggat and Hall, 2010; Kane et al., 2004). Despite inconsistency in the research literature, sensory interventions are among the services most requested by parents of children with ASD (Green et al., 2006). Over 60% of children with ASD receive sensory interventions, often in combination with other therapies, making it one of the most common types of service for ASD (Green et al., 2006). With incomplete and contradictory findings from research, the field lacks consensus as to what sensory interventions families should seek and practitioners can recommend.

To increase understanding of the different types of sensory interventions and to assess the evidence, we distinguish SIT, a clinic-based, child-centered intervention originally developed by Ayres, that provides play-based activities with enhanced sensation to elicit and reinforce the child adaptive responses, and sensory-based intervention (SBI), structured, adult-directed sensory strategies that are integrated into the child's daily routine to improve behavioral regulation.

SIT

SIT is a clinic-based intervention that uses play activities and sensory-enhanced interactions to elicit the child's adaptive responses. The therapist creates activities that engage the child's participation and challenge the child's sensory processing and motor planning skills (Ayres, 1972; Koomar and Bundy, 2002; Parham and Mailloux, 2010). Using gross motor activities that activate the vestibular and somatosensory systems (Mailloux and Roley, 2010), the goal of SIT is to increase the child's ability to integrate sensory information, thereby demonstrating more organized and adaptive behaviors, including increased joint attention, social skill, motor planning, and perceptual skill (Baranek, 2002). The therapist designs a "just-right" skill challenge (i.e. an activity that requires the child's highest developmental skills) from the child's repertoire of emerging skills and supports the child's adaptive response to the challenge (Vygotsky, 1978; Watling et al., 2011). Traditional SIT is provided in a clinic with specially designed equipment (e.g. swings, therapy balls, inner tubes, trampolines, and climbing walls) that can provide vestibular and proprioceptive challenges embedded in playful, goal-directed activities.

A widely used fidelity measure defines the active ingredients or essential elements of clinic-based SIT (Parham et al., 2007, 2011). Each element is individualized to the child and targets specific objectives. The 10 essential elements are as follows: (a) ensuring safety, (b) presenting a range of sensory opportunities (specifically tactile, proprioceptive, and vestibular), (c) using activity and arranging the environment to help the child maintain self-regulation and alertness, (d) challenging postural, ocular, oral, or bilateral motor control, (e) is challenging praxis and organization of behavior, (f) collaborating with the child on activity choices, (g) tailoring activities to present the "just-right challenge," (h) ensuring that activities are successful, (i) supporting the child's intrinsic motivation to play, and (j) establishing a therapeutic alliance with the child (Parham et al., 2007, 2011).

In addition to working directly with the child, the therapist reframes the child's behaviors to the parent or clinician using a sensory processing perspective (Bundy, 2002; Parham and Mailloux, 2010). Explaining the possible links between sensory processing and challenging behaviors, then recommending strategies that target the child's hyper- or hyporeactivity, can help caregivers and other treatment providers develop different approaches to accommodate the child's needs. By modifying the child's environments or routines to support self-regulation, the child can more fully participate in everyday activities. Recommended modifications to the child's daily routines or environments often promote a balance of active and quiet activities and opportunities for the child to participate in preferred sensory experiences (e.g. swinging in the backyard or neighborhood playground, climbing on a gym set, supervised trampoline jumping, and quiet rhythmic rocking in a low lit bedroom).

SBIs

SBIs are adult-directed sensory modalities that are applied to the child to improve behaviors associated with modulation disorders. SBIs require less engagement of the child and are intended to fit into the child's daily routine. For the purposes of this review, similar to Lang et al. (2012) and May Benson and Koomar (2010), only SBIs that activate somatosensory and vestibular systems and are believed to promote behavioral regulation were included, for example, brushing, massage, swinging, bouncing on a therapy ball, or wearing a vest. As in SIT, these interventions are based on the hypothesis that the efficiency with which the child's nervous system interprets and uses sensory information can be enhanced through systematic application of sensation to promote change in arousal state (Parham and Mailloux, 2010). SBIs, like SIT, are based on neuroscience models (e.g. Kandel et al., 2000; Lane, 2002) and clinical observations (Mailloux and Roley, 2010) supporting that certain types of sensory input, for example, deep touch and rocking, are calming and organizing, and that rhythmic application of touch (e.g. brushing) or vestibular sensation (e.g. linear swinging) has an organizing effect that promotes self-regulation (Ayres, 1979; Parham and Mailloux, 2010). A key feature of these techniques is that they are designed to influence the child's state of arousal, most often to lower a high arousal state such as agitation, hyperactivity, or self-stimulating behaviors.

Most SBIs, such as weighted blankets, pressure vests, brushing, and sitting on a ball, are used in the child's natural environment (rather than a clinic), are integrated into the child's daily routine (i.e. used as needed according to the child's arousal), and are applied by family members, teachers, or aides (i.e. an occupational or physical therapist does not administer) (e.g. Wilbarger and Wilbarger, 2002). SBIs have evolved from therapists observing how children respond to the sensation (Ayres, 1972; Koomar and Bundy, 2002); therefore, the sensory techniques have not been systematically developed through research into a manualized intervention. Most research studies on SBIs have examined the effects of a single-sensory strategy on behaviors that reflect the child's arousal or self-regulation.

For purposes of this systematic review, we define SBIs as those that (a) are based on specific assessment of the child's performance, development, and sensory needs; (b) include stated goals of self-regulation and related behavioral outcomes; and (c) require the child's active participation. Examples of sensory interventions that meet these criteria include sitting on a therapy ball, swinging, and wearing a pressure or weighted vest when used to promote calming, enhance self-regulation, or improve behavior. Evidence-based practice guidelines and fidelity measures have not been developed for these interventions. These interventions have been recommended or applied by educators, psychologists, occupational therapists, and paraprofessionals, often without a specific protocol.

Systematic reviews of SIT and SBI

Previous systematic SIT reviews using samples of children with learning disabilities, attention deficit hyperactivity disorder (ADHD), and developmental coordination disorder have reported moderate effect sizes for motor and academic outcomes when SIT was compared to no treatment (Polatajko et al., 1992; Vargas and Camilli, 1999). These reviews concluded that SITs were as effective as alternative treatments (e.g. no different than perceptual motor activities) (Vargas and Camilli, 1999).

For SIT with children with ASD, three relevant systematic reviews examined sensory motor (Baranek, 2002), occupational therapy interventions (Case-Smith and Arbesman, 2008), and SBIs (Lang et al., 2012). The two former reviews defined SIT and SBI broadly, including auditory integration therapy (electronically filtered music through high-resolution head phones) and motor activity/exercise (Baranek, 2002; Case-Smith and Arbesman, 2008), that are excluded in the current review. Using these more inclusive definitions of SIT and SBI, Case-Smith and Arbesman (2008) and Baranek (2002) found low-level evidence (Levels III and IV) that these interventions improved social interaction, increased purposeful play, and reduced hyperreactivity in young children. Each review concluded that the evidence for SIT and SBI was uncertain, noting that sensory intervention studies demonstrated methodological constraints, including convenience samples, observer bias, and inadequate controls (Baranek, 2002; Case-Smith and Arbesman, 2008). These researchers recommended that future SIT/SBI research focus on functional outcomes (in addition to sensory processing measures), link physiological and functional measures, and include long-term outcomes. In a recent review that combined SIT and SBI, Lang et al. (2012) appraised 25 studies of SIT (n = 5) and SBI (n = 20 (10 examined use of a weighted vest)). Like the other reviews, the majority of findings were "suggestive" given that 19 studies used single-subject design (Level IV evidence).

The current systematic review updates these reviews, focuses on interventions that activate the somatosensory and vestibular systems, and differentiates between SIT, based on the original work of Ayres and manualized by Parham et al. (2011), and SBI, that applies specific types of sensory input hypothesized to effect self-regulation. This review also differs from Lang et al. (2012) by including only studies in which the participants had evidence of sensory processing problems (eliminating research that applied SBIs to behaviors that were not linked to sensory processing measures).

Purpose of this study

Given the evidence for co-occurring sensory processing problems in children with ASD and the need to identify the evidence base for sensory interventions, this systematic review examined the following research question: What is the effectiveness of SIT and SBIs for children with ASD and co-occurring sensory processing problems on self-regulation and behavior?

Methods

Literature search

Several strategies were used to identify studies for this review. A computerized search of references published between 2000 and 2012 was conducted using the following electronic databases: WorldCat (Social Sciences Abstracts, Academic OneFile, and Academic Search Complete); MEDLINE, ERIC, CINAHL, and the Psychology & Behavioral Sciences Collection. Reference lists from identified articles, systematic reviews, and practice guidelines for SBIs (Watling et al., 2011) were hand searched to ensure that a comprehensive list of relevant articles was considered for inclusion.

Various combinations of the following key words and search terms were used to identify pertinent articles:

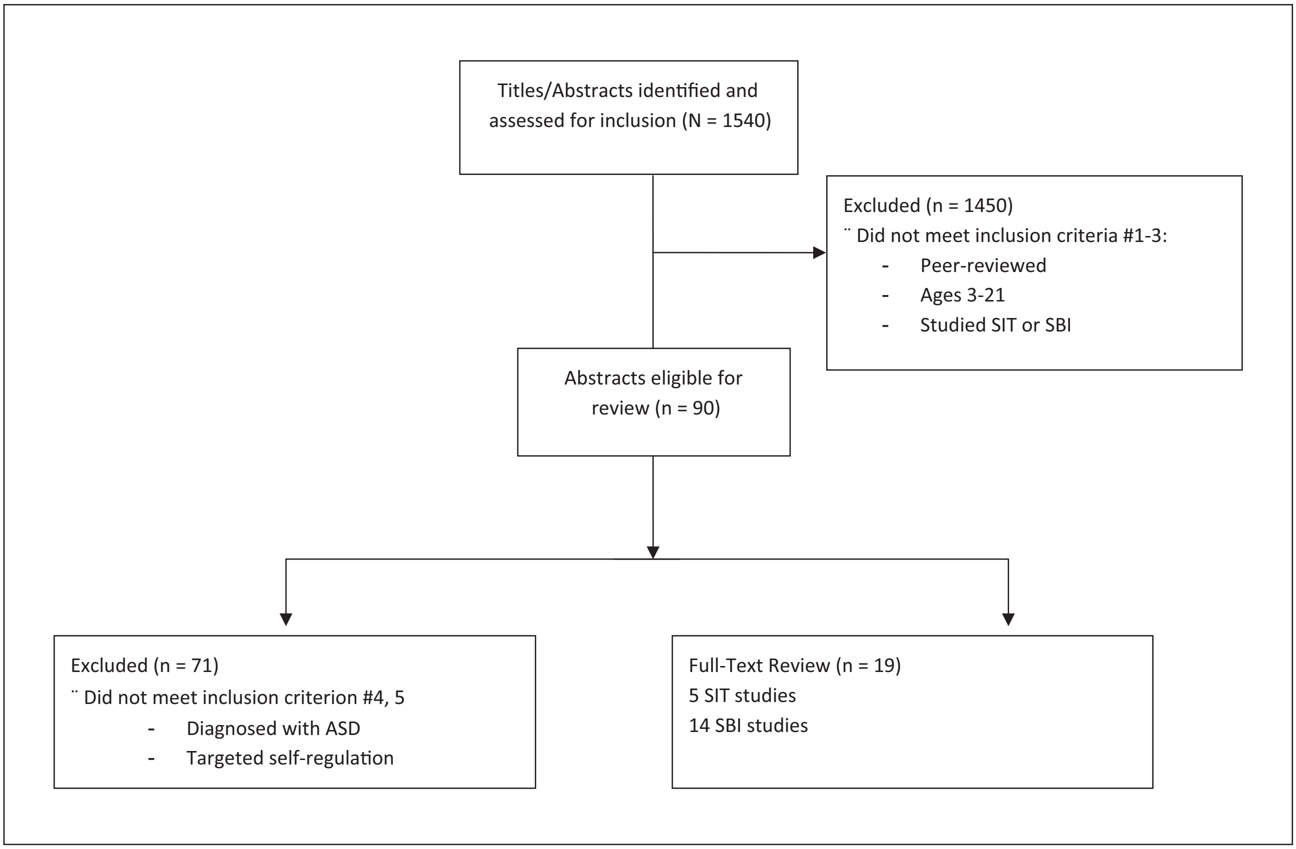

Figure 1. Flow diagram outlining results of published literature search and included studies.
SIT: sensory integration therapy; SBI: sensory-based intervention; ASD: autism spectrum disorder.

sensory integration, sensory processing, sensory-based, sensory, psychiatry, psychology, self-regulation, mental health, occupational therapy, developmental disorder, and autism. Inclusion criteria were as follows: (a) peer-reviewed studies published in English, (b) participants were youth aged 3–21 years, (c) an SIT or SBI was studied, (d) participants were diagnosed with ASD, and (e) the intervention systematically (i.e. was based on stated goals) targeted self-regulation and arousal state.

A total of 1540 references were identified through the original search process (see Figure 1). Based upon title and abstract screening, 1450 articles were excluded as they did not meet inclusion criteria #1–3. The remaining 90 abstracts were reviewed. Of those, 71 were excluded because they did not meet inclusion criterion #4 or 5. The remaining 19 studies were selected for full text review by J.C.-S. and L.L.W.

Analysis

J.C.-S. and L.L.W. analyzed the studies that met inclusion criteria and extracted the following data: (a) research objectives, (b) research design, (c) participant characteristics, (d) intervention, (e) outcome measures, and (e) findings. We used criteria developed for both rehabilitation and psychology research as these studies are published in the medical, education, and psychology literature. Overall rigor of the methodology was rated according to PEDro scale (De Morton, 2009), commonly used in occupational therapy (the field most likely to provide sensory interventions) or physical therapy to judge the rigor of clinical trials (see Center for Evidence-Based Medicine Levels of Evidence (http://www.cebm.net) and Physiotherapy Evidence Database (http://www.pedro.org.au)). The PEDro scale has 10 criteria that are scored 1 for "yes" or 0 for "no" and summed as x/10. We also used the psychology guidelines for evidence-based treatments (Chambless and Hollon, 1998; Nathan and Gorman, 2007) to rate rigor of each study (Types 1–6). The authors rated the studies independently, compared and discussed scores, and agreed on consensus scores. Table 1 presents the criteria used to analyze the studies.

Study characteristics are summarized in Table 2. Findings were synthesized in terms of type of intervention and effects on targeted outcomes. An average effect size was not calculated, as 15 of 19 studies used single-subject or case report designs.

Table 1. Common systems to describe levels of evidence and criteria used to analyze studies in psychology and occupational therapy.

Randomized controlled trial (RCT) criteria (Chambless and Hollon, 1998; Nathan and Gorman, 2007)	Types of studies (Chambless and Hollon, 1998; Nathan and Gorman, 2007)	PEDro scale (Physiotherapy Evidence Database), scores range from 0 to 10	Levels of evidence (Center for Evidence-Based Medicine)
Should include: • Comparison groups with random assignment • Blinded assessments • Clear inclusion and exclusion criteria • Standardized assessment • Adequate sample size for statistical power • Intervention manual • Fidelity measure • Clearly described statistical methods • Follow-up measures	• Type 1: most rigorous, randomized, prospective clinical trial that meets all criteria • Type 2: clinical trial, at least one aspect of the Type 1 study is missing • Type 3: clinical trial that is methodologically limited, for example, a pilot study or open trial • Type 4: review of published data, for example, meta-analyses • Type 5: reviews that do not include secondary data analyses • Type 6: case studies, essays, and opinion papers	• Random allocation used • Allocation concealed • Groups comparable at baseline • Blinding of participants • Blinding of all study therapists • Blinding of all assessors who measured at least one key outcome • Outcome measures obtained from more than 85% of the initial sample • Intent-to-treat analyses used • Between-group statistical comparisons reported • Pre/post-measures and measures of variability reported (or effect sizes reported)	• Level I: systematic review (of RCTs) or RCT conducted • Level II: systematic review of cohort studies; low-quality RCT; individual cohort study; outcomes research • Level III: systematic review of case-control studies; individual case-control study • Level IV: case series; poor quality case-control studies • Level V: expert opinion without explicit critical appraisal

Center for Evidence-Based Medicine (http://www.cebm.net) (Chambless and Hollon, 1998; Nathan and Gorman, 2007); Physiotherapy Evidence Database PEDro scale (http://www.pedro.org.au).

Results

A total of 19 studies published since 2000 met inclusion criteria. Five examined the effects of SIT and 14 examined the effects of a SBI on children with ASD and sensory processing problems (see Table 2).

SIT effects

Two of the five SIT studies were randomized controlled trials (RCTs); one RCT compared SIT to usual care, one compared SIT to a fine motor activity protocol, and one was a case report. All five studies used participants with ASD and sensory processing disorders and applied a manualized SIT approach based on the original work of Ayres (1972, 1979). Four studies (Pfeiffer et al., 2011; Schaaf et al., 2012; Schaaf et al., 2013; Watling and Dietz, 2007) documented high fidelity using the published fidelity measure described earlier (Parham et al., 2007). RCT results suggest that SIT is associated with positive effects as measured by the child's performance on Goal Attainment Scaling (GAS) (Pfeiffer et al., 2011; Schaaf et al., 2013), decreased autistic mannerisms (Pfeiffer et al., 2011), and improved (i.e. less caregiver assistance required) self-care and social function (Schaaf et al., 2013). Treatment effects on GAS, as rated by a blinded therapist who interviewed the parents, were moderate to high (Pfeiffer et al. ($\eta = .36$) and Schaaf et al. ($d = 1.17$)), reflecting child improvement on targeted goals as measured by teachers and parents. Schaaf and her colleagues also demonstrated moderate effects on sensory perceptual behaviors ($d = .6$).

In the nonrandomized SIT trial, seven children with low-functioning ASD who exhibited self-injurious and self-stimulating behaviors received alternating SIT and behavioral intervention conditions (Smith et al., 2005). The children showed fewer problem behaviors 1 h after SIT than 1 h after behavioral interventions ($p = .02$) and problem behaviors declined from weeks 1 to 4 ($p = .04$), suggesting that in children with sensory processing problems, SIT may reduce self-injurious and self-stimulating behaviors more than behavioral interventions. In the case report by Schaaf et al. (2012), a 5-year-old with ASD and ADHD improved in ritualistic behaviors, resistance to change, specific fears, and individualized goals as measured by the GAS. Using an ABAB single-subject design with four preschool children, Watling and Dietz (2007) examined the immediate effects of SIT compared to a baseline condition on engagement and behavior during a tabletop activity but found no effect for SIT. These authors noted that a ceiling effect limited their ability to detect change in performance.

Table 2. Summary of the evidence examining the efficacy of sensory integration therapy (SIT) and sensory-based interventions (SBIs) for children and adolescents.

Study	Objectives	Rating/design/participants	Intervention and outcome measures	Results	Interpretation
SIT					
Pfeiffer et al. (2011)	To determine feasibility, identify appropriate outcome measures, and address effectiveness of SI interventions in children with ASD	Type 3: pilot RCT (random assignment, single blind); PEDro score = 6/10; CEBM Level I Children with ASD; N = 37 (32 male, 5 female); ages 6–12 SI group (n = 20); fine motor (FM) group (n = 17)	*Intervention*: Experimental group: SI as defined by Parham et al. (2011); 18 sessions, 45 min each, over 6-week period. Control group: FM addressing constructional, drawing and writing, and FM crafts. Activities did not provide full-body proprioceptive, vestibular, or tactile sensory input. Matched for contact duration *Outcome measures*: SPM, QNST-II, GAS, VABS-2, SRS	Both groups improved on GAS; SI group demonstrated more significant improvement as rated by parents ($p < .01$, effect size = 0.125) and teachers ($p < .01$, effect size = 0.360). On SRS, SI group demonstrated fewer autistic mannerisms than FM group ($p < .05$, effect size = 0.131). No significant differences between other subscales of SRS or the QNST-II. No significant differences found on VABS-2 or SPM	Low to moderate effects. Design includes random assignment, blinded assessment, clear inclusion and exclusion criteria, standardized assessment, intervention manual, fidelity measure, and clearly described statistical methods. Limitations include SPM and QNST-II not established to measure changes over time; tools were not specifically designed for use with children with ASD, and no follow-up measures
Schaaf et al. (2012)	To investigate the effects of occupational therapy using a sensory integrative approach on one child with ASD and sensory processing difficulty	Type 6; case report; manualized intervention, fidelity measure; PEDro score = 3/10; CEBM Level V Child with ASD and ADHD, n = 1; age = 65 months	*Intervention*: Child received a manualized SI/occupational therapy treatment. Two OTs provided the intervention 3 times per week for 10 weeks. Fidelity was 95.5% accuracy using the OT/SI fidelity measure (Parham et al., 2011) *Outcome measures*: goal attainment scales using individualized goals; SIPT; PDDBI; VABS	The child improved on five tactile discrimination tasks and five praxis tests of the SIPT. He improved on the PDDBI in Ritualisms and Resistance to Change, and Specific Fears. On the GAS, his T score was 68, indicating better-than-expected achievements	This case study provided description of changes in one child following SI/OT for 10 weeks. The child made improvements in sensory motor performance and adaptive behaviors. Findings from a case study are not generalizable
Schaaf et al. (2013)	To evaluate the effects of SI intervention on children with ASD in comparison to usual care	Type 3; RCT (random assignment, not blinded); manualized intervention, fidelity measure; PEDro score = 6/10; CEBM Level I Children with ASD; (26 males, 6 females); N = 32; ages 56–83 SI group (n = 17) usual care group (n = 15)	*Intervention*: Children in the intervention group received a manualized SI/occupational therapy treatment. Three licensed OT provided the intervention and met fidelity criteria. The intervention was provided 3 times week for 10 weeks. The usual care group received traditional OT services in community setting *Outcome measures*: goal attainment scales using individualized goals, PEDI, PDDBI, VABS	The SI/OT group improved significantly more than UC on Goal Attainment Scaling ($p = .003$); caregiver assistance for Self Care and Social Function (PEDI; $p = .008$, $p = .039$). The groups did not differ in adaptive behaviors as measured by the VABS. Differences on the PDDBI approached significance	Low to moderate positive effects for the group that received SI/OT across two of four measures. Limitations include lack of blinding (although a blinded therapist administered the parent-report measures (GAS)), small sample size, and limited description of the usual care group. Follow-up data were not reported
Smith et al. (2005)	To compare the effects of SIT and a control intervention on self-stimulating and self-injurious behaviors (SSB and SBI) in youth with severe/profound PDD and MR	Type 3: two-group, nonrandomized control trial (not blinded); PEDro score = 5/10; CEBM Level II PDD and/or severe or profound intellectual disability with self-stimulation and self-injurious behaviors; N = 7 (4 male, 3 female); ages 8–19	*Intervention*: engage in SIT, including a variety of tactile, proprioceptive, and vestibular input. (Weeks 2 and 4 only; 30 min, 5 times per week). Video taken for 15 min prior to treatment, for 15 min after treatment, and for 15 min 1 h after treatment *Control condition*: tabletop activities related to client's educational program (sorting, coloring, and writing). Individual sessions over 4 weeks (weeks 1 and 3 only; 30 min; 5 times per week). Video taken for 15 min prior to treatment, for 15 min after treatment, and for 15 min 1 h after treatment *Outcome measures*: the SI Inventory Revised–For Individuals With Developmental Disabilities; video tapes: 15 min long prior to intervention, 15 min long after intervention, and 15 min 1 h post intervention, rating self-stimulation or self-injurious behaviors at 15-s intervals	Percentage of SSB and SBI pretreatment, posttreatment, and 60 min after treatment were compared between the SIT group and control group. Self-stimulating and self-injurious behaviors remained stable for all participants pre- or posttreatment; 1 h post SIT, frequency in SSB decreased (11%); 1 h after the control intervention, SSB increased (2%)	Low effects. Design includes control condition, clearly described statistical methods. Limitations include small sample size, single clinical site, no blinding, and lack of psychometrics for SI Inventory Revised–For Individuals with Developmental Disabilities

(*Continued*)

Table 2. (Continued)

Study	Objectives	Rating/design/participants	Intervention and outcome measures	Results	Interpretation
Watling and Dietz (2007)	To examine whether participation in Ayres' SIT immediately before tabletop tasks affects the child's engagement in or the occurrence of undesired behaviors during tabletop activities	Type 3: multiple baseline single-subject design; PEDro score = 3/10; CEBM Level IV Children with ASD; N = 4 (males); ages 3–4	*Intervention*: three phases—familiarization, baseline, and treatment. Each phase was three 40-min sessions per week. Each session was followed by a 10-min tabletop activity (data collection period). SIT sessions were based on the sensory profile results of each child, SI theory, observations of behaviors, and ongoing clinical reasoning *Outcome measures*: behaviors interfering with task engagement and engagement in play or purposeful activities were measured through direct observation	Measures of task engagement or undesired behaviors that interfered with engagement did not improve. The authors reported a ceiling effect across the measures.	No effects. Design includes two baseline phases, clear inclusion/exclusion criteria, standard intervention protocol, and a fidelity measure. Limitations include small sample size, complications in rating engagement, short duration of A2 phases, and no blinding in observations recorded by caregivers and study personnel
SBI					
Bagatell et al. (2010)	To examine the effect of therapy ball chairs on in-seat behavior and engagement	Type 3: multiple baseline single-subject Design; PEDro score = 3/10; CEBM Level IV Children in kindergarten to first grade with moderate to severe ASD; N = 6 (males); no age reported	*Intervention*: for 4 weeks, children sat on individually sized, inflated therapy ball chairs during class circle time (feet flat on ground with hips and knees at a 90° angle) *Outcome measures*: total duration of time out of seat and/or not attending to teacher or task	No consistency of results for in-seat behavior and engagement. For three students, no changes from baseline noted; one student had greater in-seat behavior, while another had less (out-of-seat behavior not recorded for one student). Individual analyses suggest that a therapy ball chair may be more appropriate for children who seek vestibular–proprioceptive input than for other patterns of sensory processing	No positive effect. Limitations include small sample size, lack of consistency of context and activity in which balls were used, short study duration, evaluation not blinded, and no fidelity measure
Cox et al. (2009)	To evaluate the impact of weighted vests on the amount of time engaged in appropriate in-seat behavior	Type 3: multiple baseline single-subject; PEDro score = 4/10; CEBM Level IV Children with ASD; N = 3 (2 male, 1 female); ages 5–9	*Intervention*: no vest (A); vest, no weight (B); weighted vest (BC) *Outcome measures*: observed duration of appropriate in-seat behavior	Weighted vests, non-weighted vests, and no vest all have a similar effect on appropriate in-seat behavior	No effects. Limitations include small sample size, evaluation not blinded, and no intervention manual. In-seat behavior is highly influenced by classroom activities
Davis et al. (2011)	To analyze the effects of a brushing protocol on stereotyped behavior of a boy with ASD	Type 3: single-subject; PEDro score = 2/10; CEBM Level IV Child with ASD; N = 1 (male); age 4	*Intervention: brushing* was used following baseline, 5 weeks of brushing, and 6-month follow-up *Outcome measures*: stereotypic behavior during five assessment conditions—attention, demand, tangible, play, and alone	Stereotypy remained unchanged across assessment conditions when brushing techniques were used	No effects. Findings for one child were reported. Limitations include use of an ABA design in which the intervention was only applied once and lack of blinding
Devlin et al. (2009)	To investigate the comparative effects of SIT and behavioral interventions on rates of self-injurious behavior	Type 3: single-subject; PEDro score = 3/10; CEBM Level IV Child with ASD; N = 1 (male); age 10	*Intervention*: SBI—swinging, deep pressures with beanbag, rocking, jumping, crawling, chew tube, brushing, and joint compression; behavioral intervention—functional analysis, requests, and reinforcement *Outcome measures*: Occurrence of self-injurious behaviors as measured in 10-s intervals	Child exhibited fewer self-injurious behaviors during the behavioral intervention than during the SBI	Effects of behavioral intervention were greater than SBI effects. Functional analysis and tailoring of intervention for the behavioral approach only. Limitations include short-term intervention (16 days), no blinding
Devlin et al. (2011)	To compare the effects of SIT and a behavioral intervention on rates of challenging behavior	Type 3: multiple baseline single-subject; PEDro score = 4/10; CEBM Level IV Children with ASD; N = 4 (male); ages 6–11	*Intervention*: SBI—swinging, jumping, therapy balls, wrapping in blanket, joint compressions, deep pressure with beanbag, chew tube, and brushing; behavioral intervention—operate condition based on functional behavioral analysis *Outcome measures*: Frequency of challenging behavior; stress levels as measured by cortisol	Challenging behaviors were greater during the SBI than during the behavioral intervention (comparing a 5-day baseline to 10 days of intervention). Cortisol levels were slightly higher in the SBI condition; however, these results were not significant	Behavioral intervention was more effective in reducing challenging behaviors than SBI. Limitations include a short period of intervention (10 days), small sample (four participants), lack of blinding, and desperate application of intervention (behavioral intervention used functional analysis, SBI did not)

Table 2. (Continued)

Study	Objectives	Rating/design/participants	Intervention and outcome measures	Results	Interpretation
Fazlioglu and Baran (2008)	To develop and test a program of SIT for use in assessment and treatment of autistic children	Type 3: RCT (random assignment, not blinded); PEDro score = 6/10; CEBM Level II Children with ASD; N = 30 (24 male, 6 female); ages 7–11 Intervention group (n = 15); control group (n = 15)	*Intervention*: based on "The Sensory Diet." Includes a schedule of brushing and joint compression followed by a set of individualized sensory activities that was integrated into the child's daily routine. Behavioral strategies (prompting, reinforcement, and extinction) were also used to teach targeted motor behaviors identified by The Sensory Evaluation Form for Children with Autism *Outcome measures*: the Sensory Evaluation Form For Children With Autism (a checklist created by the researchers) was used to determine sensory processing problems	Statistically significant interaction effects on sensory behaviors for group × time (F = 119.38, $p < .01$)	Strong effects. Results are difficult to generalize. Design includes random assignment, adequate statistical power. Limitations include limited description of the sensory intervention, lack of a fidelity measure, use of a non-standardized measure, no blinding, and no follow-up
Fertel-Daly et al. (2001)	To examine the effects of wearing a weighted vest on attention to task and self-stimulatory behaviors of five preschool children with ASD	Type 3: multiple baseline single-subject; PEDro score = 3/10; CEBM Level IV *Outcome measures*: time on task, number of distractions, and self-stimulatory behaviors were measured through direct observation	*Intervention*: wearing a weighted vest Children with ASD; N = 5 (3 male, 2 female); ages 2–3	All participants showed decreased number of distractions and time on task while wearing the vest. Four out of five participants showed decreased self-stimulation and, for two children, remained decreased when intervention was removed. Self-stimulation increased during intervention for one participant	Moderate effects. Design includes control condition; clearly described statistical methods. Limitations include small sample size, use of vest in one setting, and evaluation not blinded
Hodgetts et al. (2011)	To investigate the effects of weighted vests on stereotyped behaviors in children with ASD and to test the effects of weighted vests on heart rate	Type 3: multiple baseline single-subject; PEDro score = 5/10; CEBM Level IV Children with severe ASD; N = 6 (5 male, 1 female); ages 4–10	*Intervention*: (a) wearing a weightless vest with Styrofoam balls in place of weights, (b) vests weighed at 5%–10% of child's body weight *Outcome measures*: videotaped sessions were coded for stereotypy and heart rate monitor was used for measuring heart rate	Among all participants, motoric stereotyped behaviors or heart rate did not decrease. Heart rate increased for one participant. One child demonstrated decreased verbal stereotypy	No effects. Study suggests that when using weighted vests, the following must be completed: a functional analysis of target behavior and desired outcomes defined a priori and monitored systematically. Design includes blinding of raters/children to treatment condition. Limitations include no functional analysis of behaviors and small sample size
Hodgetts et al. (2010)	To examine whether touch-pressure sensory input through a weighted vest decreases off-task behavior and increases sitting time; to evaluate whether teachers and educational assistants view weighted vests as a tool to enable children with ASD to function more productively	Type 3: multiple baseline single-subject; PEDro score = 5/10; CEBM Level IV Children with moderate to severe ASD; N = 10 (8 male, 2 female); ages 3–10	*Intervention*: (a) wearing a weightless vest with Styrofoam balls in place of weights, (b) vests weighed at 5%–10% of child's body weight *Outcome measures*: direct observation was used to measure off-task behavior and time in-seat. The 10-item CGI-T was used to rate restlessness, impulsivity, and emotional lability	No effect on time in-seat for three participants. Vests were effective in decreasing off-task behavior for three participants and ineffective for five participants. CGI-T scores did not correspond well with video observations	Low effects. Weighted vests may be a suitable component of intervention for some children, but should not be the sole approach to improving adaptive behavior. Design includes control condition and rater blinding. Limitations include small sample size, investigated only select target behaviors, homogenous sample, phase length predetermined, and no follow-up
Kane et al. (2004)	To evaluate the effects of wearing a weighted vest on stereotypy and attention to task	Type 3: multiple baseline single-subject; PEDro score = 2/10; CEBM Level IV Children with ASD; N = 4 (2 male, 2 female); ages 8–11	*Intervention*: wearing a weighted vest, a non-weighted vest, or no vest *Outcome measure*: occurrence of stereotypy and attention to task during ten 1-min intervals	Occurrence of stereotypy and attention to task did not vary as a function of wearing a vest	No effects. Limitations include a short intervention timeline (three sessions), small sample (four participants), and lack of blinded assessment

(Continued)

Table 2. (Continued)

Study	Objectives	Rating/design/participants	Intervention and outcome measures	Results	Interpretation
Leew et al. (2010)	To examine whether the use of weighted vests facilitated an increase in joint attention in toddlers	Type 3: multiple baseline single-subject; PEDro score = 4/10; CEBM Level IV *Outcome measures*: the PMI measured parenting morale. Direct observation was used to measure joint attention and behaviors that compete with joint attention	*Intervention*: wearing a weighted vest Children with autism; N = 4 (male); ages 27–33 months	Weighted vests did not decrease problem competing behaviors or increase joint attention in toddlers with ASD. Changes in PMI were not significant for three out of four mothers	No effects. Limitations include small sample size, vests used in the study may not provide amount of deep pressure needed for optimal effect on nervous system, and lack of fidelity and follow-up measures
Reichow et al. (2010)	To examine the use of a weighted vest on engagement of young children with autism or developmental delay	Type 3: multiple baseline single-subject; PEDro score = 4/10; CEBM Level IV Children with ASD; N = 2 (male); age 5	*Intervention*: three conditions were compared: wearing a weighted vest, a vest with no weight, and no vest *Outcome measures*: behavior when wearing the vest or the control conditions: (a) engagement, (b) nonengagement, (c) stereotypic behavior, (d) problem behavior, and (e) unable to see child	There were no systematic differences in engagement, stereotypic behavior, or problem behavior for one participant between conditions. In the other child, problem behavior increased and stereotypic behavior decreased when the vest was worn. The vests were not effective for increasing engagement for the participation during table activities	Mixed effects for one child and no effects for one child. One child had few problem or stereotypic behaviors. Limitations include small sample, lack of potential variance in behavior, and lack of blinded assessment
Schilling and Schwartz (2004)	To investigate the effects of therapy balls as seating on engagement and in-seat behavior	Type 3: multiple baseline single-subject; PEDro score = 3/10; CEBM Level IV Children with ASD; N = 4 (male); ages 3–4	*Intervention*: withdrawal design using an individually fitted therapy ball for seating *Outcome measures*: momentary real-time sampling was used to measure sitting and engagement behaviors	Results indicate that all participants displayed marked improvement in engagement and in-seat behavior during use of the therapy balls	High effects. Design includes control condition. Limitations include small sample size, assignment to treatment condition, evaluation not blinded, and lack of fidelity and follow-up measures
Van Rie and Heflin (2009)	To determine whether there is a functional relationship between sensory activities and correct responding	Type 3: multiple baseline single-subject; PEDro score = 3/10; CEBM Level IV Children with ASD; N = 4 (male); ages 6–7	*Intervention*: swinging or bouncing on an exercise ball for 5 min before a targeted activity *Outcome measure*: correct responding to academic tasks	Correct responding to academic tasks was not related to sensory stimulation prior to the academic task	Mixed effects. For one participant bouncing on the ball related higher correct responding; for two participants, swing was associated with higher correct responding; for one participant, the SBI had no effects. Limitations include small sample, short time frame, lack of blinding, and desperate measures across participants

SI: sensory integration; ASD: autism spectrum disorders; RCT: randomized controlled trial; CEBM Level: level of rigor based on guidelines from the Center for Evidence-Based Medicine (2011); GAS: Goal Attainment Scaling; SRS: Social Responsiveness Scale; QNST-II: Quick Neurological Screening Test; VABS: Vineland Adaptive Behavioral Scales; SPM: Sensory Processing Measure; OT: occupational therapist; SIPT: SI and Praxis Tests; PDDBI: Pervasive Developmental Disorder Behavioral Inventory; ADHD: attention deficit hyperactivity disorder; UC: usual care; PEDI: Pediatric Evaluation of Disability Inventory; SSB: self-stimulatory behavior; MR: mental retardation; CGI-T: Conner's Global Index–Teacher; PMI: Parenting Morale Index; PEDro: the Physiotherapy Evidence Database; PEDro score: a rating based on the PEDro scale (1999) designed to judge the quality and usefulness of trials to inform clinical decision making; Type: coding of study design based on Nathan and Gorman (2007) guidelines.

SBI effects

A total of 14 studies that applied SBI met our criteria (we excluded eight studies that were included by Lang et al. (2012) because the participants did not have evidence of sensory processing problems (no baseline measures of sensory processing)). Thirteen studies used single-subject design; seven studies examined the effects of a weighted vest (Cox et al., 2009; Fertel-Daly et al., 2001; Hodgetts et al., 2010, 2011; Kane et al., 2004; Leew et al., 2010; Reichow et al., 2010), two examined sitting on therapy balls (Bagatell et al., 2010; Schilling and Schwartz, 2004), one evaluated brushing (Davis et al., 2011), and three examined multiple-sensory strategies (Devlin et al., 2009, 2011; Van Rie and Heflin, 2009). For all but one study (Davis et al., 2011), the interventions took place in schools and educational centers. One study from Turkey (Fazlioglu and Baran, 2008) examined a multisensory intervention in a randomized trial of 30 children with ASD (15 interventions and 15 controls). An educator applied a "sensory diet" protocol, exposing the children to different sensations and practicing specific movements.

Outcomes provide very limited evidence of positive effects. Seven studies, each using multiple baseline single-subject design, examined the effects of a weighted vest on children with ASD and sensory processing problems. Six of the seven studies included a non-weighted vest condition and four studies included a control (no vest) condition. In each, behaviors were measured across multiple phases of wearing the weighted vest. Only one study (n = 5) demonstrated a positive effect on children's attention and mixed effects on distractibility (Fertel-Daly et al., 2001). Of the six studies that demonstrated no effects when wearing a weighted vest, five measured stereotypic behaviors (Cox et al., 2009; Hodgetts et al., 2010, 2011; Kane et al., 2004; Reichow et al., 2010) and three measured attention or engagement (Kane et al., 2004; Leew et al., 2010; Reichow et al., 2010).

Two multiple baseline single-subject studies of therapy balls showed mixed effects (Bagatell et al., 2010; Schilling and Schwartz, 2004). In both studies, young children (3–7 years) with ASD sat on therapy balls during classroom activities to support their self-regulation. Schilling and Schwartz (2004) found that all of the children (n = 4) demonstrated more in-seat and engaged behaviors when sitting on the therapy ball. Bagatell et al. (2010) found that sitting on a ball resulted in increased in-seat behavior for one child, no effects for four children, and decreased in-seat behavior for one child. Engagement was highly variable and was not affected by sitting on a ball. In an ABA single-subject design study, Davis et al. found no effects on stereotypical behavior from administration of a brushing protocol.

Four studies used a combination of different types of vestibular stimulation, for example, swinging or bouncing (Van Rie and Heflin, 2009) or a sensory diet of primarily brushing, swinging, and jumping (Devlin et al., 2009, 2011; Fazlioglu and Baran, 2008). Two studies by Devlin et al. found no effects from the multisensory stimulation on self-injurious behaviors; one study (Van Rie and Heflin, 2009) demonstrated positive effects on behaviors related to self-regulation. Van Rie and Heflin (2009) examined students' correct responses to academic tasks immediately following swinging or bouncing and found that three of four made more correct responds during the sensory stimulation condition. Fazlioglu and Baran found a strong effect (d = 2.1) in reducing sensory problems; however, limitations of this RCT include no report of blinded evaluation or use of a fidelity measure and limited description of the SBIs. In addition, they used behavioral techniques, including modeling, prompting, cueing, and fading that likely confounded the intervention effects. These studies lacked standardized or blinded evaluation, fidelity measures, and a manualized or standardized intervention protocol for SBI, limiting replication and generalization.

Discussion

As previously noted, SIT and SBI are among the most widely used interventions for children with ASD. Although families seek these interventions (Green et al., 2006), they can be misunderstood by practitioners (Botts et al., 2008) and have been defined differently by researchers (e.g. Lang et al., 2012). Because SBIs designed to support a child's self-regulation are ideally implemented when the child's arousal is too high or low, effects may not result when the strategies are applied using a protocol applied once-a-day that does not consider the child's arousal state. SIT originated in the 1960s and 1970s (Ayres, 1972, 1979) and is most often provided by occupational therapists. The clinic-based approach focuses on the therapist–child relationship and uses play-based activities that provide a "just-right" sensory motor challenge (scaffolding the child's emerging skills) to elicit adaptive responses in the child. The therapist–child relationship and the systematic design of activities that challenge the child while enhancing self-regulation, for example, promoting optimal arousal, and increasing appropriate behaviors, may be the primary change-producing elements.

Using the criterion that SIT studies adhere to the published rationale, purpose, and description of sensory integration intervention (Ayres, 1979; Bundy et al., 2002; Parham et al., 2007), five studies were identified. The RCTs that examined the effects of a manualized SIT found meaningful positive effects (effect sizes ranging from .72 to 1.17) on GAS (the child's individualized goals) (Pfeiffer et al., 2011; Schaaf et al., 2013).

Because SIT activities focus on a child's foundational abilities to attend and learn (e.g. sensory integration, self-regulation, and self-efficacy), rather than teach and practice specifically targeted behaviors, the immediate treatment effects may be more diffuse than those of behavioral interventions; it is unknown whether SIT has more sustained and generalized effects. Recognizing that the RCTs had small samples, SIT shows moderate effects on parent- or teacher-reported measures. It is premature to draw conclusions as to whether SIT for children with ASD, which is designed to support a child's intrinsic motivation and sense of internal control, is ultimately effective. The emphasis on play and child-centered activities may promote the child's ability to generalize learning in play and preferred activities. In practice, SIT is often combined with behavioral, motor, and self-care approaches, and as such, a comprehensive approach may produce desired outcomes.

SBIs are single-sensory strategies or a combination of sensory strategies applied to the child, most often in the school environment. Among the seven single-subject studies that applied a weighted vest, only one demonstrated positive effects. Although these studies provide low-level evidence, findings suggest that wearing a weighted vest does not result in improved behavior (e.g. decreased stereotypic behaviors, improved joint attention, or reduced distractibility). The evidence for children sitting on balls or for multisensory stimulation is limited and inconclusive (e.g. Bagatell et al., 2010; Davis et al., 2011; Schilling and Schwartz, 2004). Although one SBI study using multisensory input found strong effects, its methodological limitations reduce confidence in the findings (Fazlioglu and Baran, 2008). Lack of blinded evaluation, limited description of the intervention and control conditions, use of a non-standardized measure (checklist), and confounding the "sensory diet" with behavioral techniques reduce the certainty of findings (that were rated as "suggestive" by Lang et al. (2012)). In sum, the evidence for SBI is insufficient to recommend their use.

As described in qualitative studies, parents may intuitively adapt their family's routine and the home environment for children with sensory processing problems (Bagby et al., 2012; Schaaf et al., 2011). In addition, occupational therapists and other practitioners consult with families to help them adapt their routines and environments to accommodate a child's sensory processing difficulties. For example, families adopt highly structured routines, avoid highly stimulating environments, prepare the child for transitions and potentially aversive sensory experiences, develop strategies that support the child's self-regulation, and show flexibility when the child is unable to cope. Persons with ASD and sensory processing problems (e.g. Grandin, 1995; Williams, 1995) have described how they adapted their environments and routines to meet their sensory needs. This systematic review suggests that the use of single-sensory strategies (i.e. SBIs) when implemented in school environments may not be effective, particularly when they are not individualized to the child's sensory processing problem.

Limitations

By establishing a strict definition of sensory interventions, only 19 studies met our inclusion criteria. Of these, only three were RCTs (Type 3; Nathan and Gorman, 2007); the majority of studies were multiple baseline single-subject design. The studies did not use blinded evaluation, used small samples, examined short-term interventions, and did not examine retention of intervention gains.

Implications for research and practice

Children with ASD have sensory processing problems; effective interventions to ameliorate the discomfort and distress associated with these problems are needed. Families report that managing the extreme sensory needs of children with ASD can be highly stressful, given the unpredictable nature of children's responses to new experiences and stimulating environments (Bagby et al., 2012). When selecting interventions to support the child's self-regulation, the therapist's roles and levels of engagement and the intervention context should be considered. A key difference between SIT and SBI is the role of the child (child-centered vs adult-directed). Child-centered interventions that allow the child to initiate and select activities are designed to enhance intrinsic motivation, interest in the environment, and playful intent. In the long term, child-directed interventions are thought to build the child's self-esteem and intrinsic motivation to learn (Parham and Mailloux, 2010). Many ASD interventions, including SBI, are adult-directed, adhering to the rationale that children with ASD respond to highly structured activities (Smith and Eikeseth, 2011). Adult-directed interventions can result in immediate behavioral change (Odom et al. 2012), but may not generalize to child-initiated behaviors across settings (e.g. Kasari et al., 2006). A thoughtful approach that alternates between and uses both approaches over time may result in optimal outcomes (Kasari et al., 2006; Landa, 2007).

While SIT is provided in a clinic environment, SBIs are most often embedded in the school environment and child's daily routine. Our findings suggest that sensory interventions applied in the school context may not have benefit. Reasons for limited effectiveness may be a mismatch between the goals and intent of SBI and the child's academic learning, lack of training of the adult who applied and monitored the sensory strategies, misunderstanding of how and for whom the sensory strategies would be beneficial, and lack of potency. SIT allows the child and therapist to focus on specific goals during one-on-one, sensory-enhanced, play-based sessions that are individualized to the child, suggesting more opportunities to affect behavior and attain positive outcomes. Context, that is, clinic versus school, may influence efficacy and be a salient variable to consider when planning sensory interventions.

Although clinicians and researchers have linked sensory processing disorders to difficulties in maintaining optimal arousal and regulating behavior (e.g. Miller et al., 2007a), this relationship has not been well researched. To understand how arousal and autonomic nervous system function relate to behaviors indicating hyper and hyporeactivity, researchers have used a variety of physiological measures (e.g. cortisol, galvanic skin response, and heart rate variability) (e.g. Gabriels et al., 2013). Children with ASD demonstrate greater between- and within-subject variability in daily cortisol responses than children without ASD, suggesting higher levels of dysregulated behavior (Corbett et al., 2009). Low morning and elevated evening cortisol imply a pattern of chronic stress and cumulative stress throughout the day that is possibly related to chronic overarousal. Consistent patterns of arousal and hypo- or hyperreactivity have not been identified, and universally researchers have found high variance in sensory processing and arousal patterns among children with ASD (Ben-Sasson et al., 2009; Corbett et al., 2009; Gabriels et al., 2013).

Recent SIT studies (e.g. Schaaf et al., 2013) have included heart rate variability measures to examine how intervention can influence basic arousal patterns. In a sample of children with sensory processing problems, Miller et al. (2007a) found changes in galvanic skin response during SIT; however, variability was too high to determine meaningful differences. By using physiological measures in studies of SIT and SBI, future studies can determine whether behavioral changes relate to physiological changes, potentially linking sensory processing and arousal to behavioral regulation. Physiological measures may allow discovery of how, or if, sensory interventions influence arousal and moderate autonomic nervous system functions and how physiological changes influence behavior.

SIT goals with children who have ASD (e.g. to promote self-regulation, self-efficacy, and optimal arousal) complement the goals of other interventions or educational programs. It is most often used in combination with behavioral or psychological interventions as part of comprehensive programming. Future studies that examine the effects SIT when combined with other interventions can estimate the added benefit, if any, and may reflect how SIT is most commonly applied in practice.

Evidence for SBI for children with ASD is lacking. Studies have not followed clinical protocols defining how sensory strategies are carefully matched to the child's sensory processing problems (e.g. sitting on a ball or jumping on a trampoline may benefit a child with hyporeactivity to vestibular input), selected by the child (or based on the child's preferences), and carefully monitored to gauge the child's responses (see Bundy et al., 2002; Watling et al., 2011).

Conclusion

Sensory processing problems are prevalent in children with ASD; however, further research is needed to identify how sensory processing, that is, hypo- and hyperreactivity, affects arousal, relates to self-regulation, and influences behavior. This systematic review of sensory interventions found that SIT for children with ASD and sensory processing problems demonstrates positive effects on the child's individualized goals; however, additional studies are needed to confirm these results. Randomized trials using blinded evaluation and larger samples are needed. SBIs have almost no evidence of positive effects. Most SBI studies lacked rigor and protocols varied widely. As specific protocols to improve sensory processing are developed and tested, they should target the child's functional performance and participation in eating, sleeping, daily activities in home and school, and community activities.

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