
Systematic Review of the Research Evidence Examining the Effectiveness of Interventions Using a Sensory Integrative Approach for Children

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KEY WORDS

- activities of daily living
- evidence-based practice
- pediatrics
- review
- sensory integrative therapy
- treatment outcome

Twenty-seven studies were systematically reviewed to identify, evaluate, and synthesize the research literature on the effectiveness of sensory integration (SI) intervention on the ability of children with difficulty processing and integrating sensory information to engage in desired occupations and to apply these findings to occupational therapy practice. Results suggest the SI approach may result in positive outcomes in sensorimotor skills and motor planning; socialization, attention, and behavioral regulation; reading-related skills; participation in active play; and achievement of individualized goals. Gross motor skills, self-esteem, and reading gains may be sustained from 3 mo to 2 yr. Findings may be limited by Type II error because of small sample sizes, variable intervention dosage, lack of fidelity to intervention, and selection of outcomes that may not be meaningful to clients and families or may not change with amount of treatment provided. Replication of findings with methodologically and theoretically sound studies is needed to support current findings.

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More U.S. occupational therapy practitioners work in pediatrics than in any other area of occupational therapy. Approximately 90% of American occupational therapists who work in school settings use the sensory integration (SI) theory and principles as originally outlined by Ayres (1972, 1979) in their interventions with children with learning disabilities (Storch & Eskow, 1996), attention deficit hyperactivity disorder (ADHD), autism, and behavior problems that may be related to difficulties organizing and processing sensory information (Miller & Fuller, 2006). Yet, after 37 years SI continues to be critiqued and its effectiveness is questioned within occupational therapy as well as within the fields of education, psychology, and medicine (Hoehn & Baumeister, 1994; Leong & Carter, 2008; Polatajko, Kaplan, & Wilson, 1992; Shaw, 2002). With current emphasis on evidence-based practice, these criticisms have implications for the occupational therapy practitioners' ability to achieve the goal of best practice, as well as for the willingness of third-party payers to reimburse these services. Because of the large number of children who experience problems processing and integrating sensory information (Ahn, Miller, Milberger, & McIntosh, 2004) and the widespread nature of functional difficulties associated with these problems, occupational therapy practitioners need research evidence to determine the effectiveness of interventions that use the SI approach.

Authors of previous reviews have suggested that research examining the effectiveness of the SI approach did the following:

- Demonstrated significant effects for the SI approach over no treatment (Ottenbacher, 1982b; Vargas & Camilli, 1999);
- Did not support SI as an effective treatment of academic problems and was unclear on whether the SI approach was more effective than perceptual–motor approaches (Polatajko et al., 1992);

- Demonstrated it to be unproven and ineffective (Hoehn & Baumeister, 1994); and
- Had medium effect sizes for psychoeducational and motor outcomes and was as effective as alternative interventions (Vargas & Camilli, 1999).

Clearly, there has been no consensus in the literature on the effectiveness of the SI approach. Recent studies have highlighted methodological problems that may have influenced these outcomes (Miller, Schoen, James, & Schaaf, 2007; Parham et al., 2007). These problems are consistent with difficulties found in intervention effectiveness research in other areas of occupational therapy, such as hand therapy (MacDermid, 2004), and other fields such as psychology (Jacobson & Truax, 1991) and medicine (Moher et al., 1994). Thus, although numerous studies examining the effectiveness of the SI approach and a few systematic reviews have been conducted over 37 years, there has not been one comprehensive systematic evidence-based review of all individual articles that investigate the effectiveness of the SI approach to date. Nor has there been an examination of this body of evidence in regard to these methodological problems.

The purpose of this review is to identify, evaluate, and synthesize the research literature on studies examining the SI approach and to provide information that may be used in clinical practice to guide intervention planning and that may contribute to our ability to refine, revise, and advance knowledge, theory, and research related to the use of the SI approach. Consumers and occupational therapy practitioners need evidence-based reviews to provide support for clinical education, to direct future research endeavors, and to promote best practices in the selection of therapeutic approaches for assisting people with their ability to effectively engage in activities of daily living (ADLs), instrumental activities of daily living (IADLs), education, play and leisure activities, and social participation.

Background Literature

Since 1972, 27 research studies have been conducted that examine the effectiveness of the SI approach as it pertains to the question asked in this review. Collectively, 19 of these studies have been included in at least one of the two meta-analyses (Ottenbacher, 1982b; Vargas & Camilli, 1999) or the three systematic reviews on the topic (Baranek, 2002; Hoehn & Baumeister, 1994; Polatajko et al., 1992). Although many of the 27 individual studies were included in these previous reviews, 2 of these reviews (Ottenbacher, 1982b; Vargas & Camilli, 1999) included studies conducted on populations (e.g., people with mental retardation, adults) not included in the current review

question. Baranek (2002) included a study in the SI section of her review that was not an actual intervention study (Ayres & Tickle, 1980), and Hoehn and Baumeister's (1994) review consisted of studies previously reviewed by Polatajko et al. (1992), with only 1 new study (Ottenbacher, 1982a). Since these reviews have been conducted, 8 additional studies have been published that have not been reviewed. These include 2 Level I studies (Miller, Coll, & Schoen, 2007; Wilson & Kaplan, 1994), 1 Level II study (Bundy et al., 2007), 1 Level III study (Miller, Schoen, et al., 2007), and 4 Level IV studies (Allen & Donald, 1995; Candler, 2003; Leemrijse, Meijer, Vermeer, Adèr, & Diemel, 2000; Roberts, King-Thomas, & Boccia, 2007). To date, no review has examined all of the individual studies on the SI approach with the populations designated in this study. (This review includes articles through 2007; studies have been published since then that are not included in this review.)

Method for the Evidence-Based Review

This study examined the following research question:

What is the effectiveness of interventions using the SI approach (including the effect of context [cultural, physical, social, personal, spiritual, temporal, and visual]) to create, promote, establish, restore, maintain, modify, and prevent future limitations in ADLs, IADLs, education/transition, play/leisure, and social participation in children and adolescents whose SI and processing patterns are interfering with everyday life participation?

For this review, criteria were established regarding inclusion of studies, participants, and interventions. Regarding interventions, studies included were those in which the authors reported the intervention to be based on the SI approach as outlined by A. Jean Ayres, yet authors appeared to interpret these principles in somewhat different ways. Participants were specifically screened and identified as having difficulty processing and integrating sensory information. All control groups were children with clinical problems unless specifically indicated otherwise. See Table 1 for more information.

Detailed information about the methodology for the entire American Occupational Therapy Association Sensory Integration Evidence-Based Literature Review can be found in the article "Background and Methodology of the Sensory Integration Evidence-Based Systematic Literature Review" (Arbesman & Lieberman, 2010). An evidence table that summarizes the 27 articles related to the effectiveness of the SI approach and includes information about the objectives, design, procedures, findings, and

Table 1. Quality Score, Population, *M*, Type of Intervention, Number and Length of Intervention Sessions, Frequency and Duration of Intervention Sessions, and Total Hours of Intervention of Sensory Integration Intervention Studies

Studies	Quality Score	Population	Intervention Type (<i>n</i>)			Intervention Dosage			Total Hr
			SI	No Treatment	Alternative Treatment	No. Sessions (Min/Session)	Frequency/Wk	Duration	
Level I									
Carte, Morrison, Sublett, Uemura, & Setrakian (1984)	.54	LD	10, 13	20	—	66 (45)	2–3	9 mo	49.5
Grimwood & Rutherford (1980)	.50	At-risk reading	9	10	—	48 (30)	2	24 wk	24
Humphries, Wright, McDougall, & Vertes (1990)	.65	LD	10	10	10 ^a	24 (60)	1	24 wk	24
Humphries, Wright, Snider, & McDougall (1992)	.71	LD	35	33	35 ^a	72 (60)	3	8 mo	72
Humphries, Snider, & McDougall (1993)	.71	LD	33	33	35 ^a	72 (60)	3	8 mo	72
Miller, Coll, & Schoen (2007)	.75	SMD	7 ^b	7	10 ^c	20 (60)	2	10 wk	20
Morrison & Sublett (1986)	.67	LD–Reading delay	18	21	—	66 (—)	2	8.5 mo	—
Polatajko, Law, Miller, Schaffer, & McNab (1991)	.77	LD	35	—	32 ^a	24 (60)	1	6 mo	24
Werry, Scaletti, & Mills (1990)	.60	LD	39	35	—	11–18 (60)	1	4–5 mo	13
White (1979)	.54	At-risk reading	11	10	—	48 (30)	2	6 mo	24
Wilson, Kaplan, Fellowes, Gruchy, & Faris (1992)	.83	LD	14	—	15 ^d	75 (50)	2	12 mo	62.5
Wilson & Kaplan (1994)	.79	LD	11	—	11 ^d	75 (50)	2	12 mo	62.5
Ziviani, Poulsen, & O'Brien (1982)	.52	LD	8 ^e	—	8 ^f	13 (90)	1	13 wk	19.5
Level II									
Ayres (1972)	.54	LD	30	42	12 ^f	100–125 (25–40)	5	5–6 mo	50
Ayres (1977)	.54	LD/choreoathetosis	31	—	23 ^f	130 (30)	5	6 mo	65
Bullock & Watter (1978)	.27	LD	78 ^g	7	—	— (—)	—	6 mo	—
Bundy, Shia, Qi, & Miller (2007)	.69	SMD	20 ^b	20 ^h	—	20 (60)	2	10 wk	20
Schroeder (1982)	.38	Neurological problems	5	5 ^h	5, 5 ⁱ	32 (45)	2	16 wk	24
Level III									
Candler (2003)	.33	SMD	12 ^j	—	—	—	5	1 wk	—
Miller, Schoen, et al., (2007)	.65	SMD	30 ^b	—	—	20 (60)	2	10 wk	20
Ottenbacher, Short, & Watson (1979)	.38	LD	43	—	—	— (60)	5	>6 mo	—
Level IV									
Allen & Donald (1995)	.44	Motor delays	5 ^b	—	—	16 (60)	1	6 mo	16
Case-Smith & Bryan (1999)	.60	Autism	1	—	—	10 (30)	1	10 mo	5
Leemrijse, Meijer, Vermeer, Adèr, & Diemel (2000)	.63	DCD	6 ^k	—	—	12–18 (60)	1	12–18 wk	15
Linderman & Stewart (1999)	.58	Autism	2	—	—	11 wk, 7 wk (60)	1	11, 7 wk	10
Ottenbacher (1982a)	.56	LD	3	—	—	60 (50)	3	20 wk	50
Roberts, King-Thomas, & Boccia (2007)	.60	SMD	1	—	—	21 (60)	3	7 wk	21

Note. Quality score determined by means of the MacDermid Scale (MacDermid, 2004). — = not applicable or not included in the article; DCD = developmental coordination disorder; LD = learning disabled; OT = occupational therapy; SI = sensory integration; SMD = sensory modulation disorder.

^aPerceptual–motor intervention. ^bOT/SI approach. ^cActivity group. ^dTutoring. ^eNeurodevelopmental and occupational therapy using the SI approach. ^fRemedial classroom activities. ^gSI and home activity. ^hTypical group. ⁱRosner Curriculum, both approaches. ^jSI/therapeutic horseback riding camp. ^kSI/Le Bon Départ.

limitations of the review studies is available at www.ajot.ajotpress.net (navigate to this article, and click on “supplemental materials”).

Results

Five review articles examined the effectiveness of the SI approach. An early meta-analysis by Ottenbacher (1982b) concluded that the SI approach demonstrated a large, significant, positive treatment effect in the area of motor outcomes in children with learning disabilities and mental retardation of diverse ages compared with no-intervention control participants. Subsequent review of

individual studies generally support Ottenbacher’s finding of positive effects of the SI approach compared with no treatment; however, the magnitude of effect found by Ottenbacher has not been replicated in subsequent reviews.

A meta-analysis by Vargas and Camilli (1999) found moderate effects in the areas of motor performance and psychosocial outcomes for the SI approach compared with no treatment, although they found no difference in effectiveness of the SI approach compared with other approaches, such as the perceptual–motor approach. They questioned differences in effects between older studies and more recent studies and concluded that there was insufficient evidence to determine the effectiveness of

the SI approach. Methodological questions arise with this study in regard to its inclusion of adults and children with mental retardation, the method of dichotomous coding of many variables, the determination of quality of intervention, and the methods of weighting variables.

A systematic review by Polatajko et al. (1992) of 10 intervention studies for children with learning disabilities concluded that the SI approach was as effective, but no more so, than other interventions and that the best gains were made in the areas of motor performance. A later systematic review by Hoehn and Baumeister (1994) re-examined 7 of the 10 studies examined by Polatajko et al. (1992) as well as 1 additional study (Ottenbacher, 1982a) and found that, although there were positive outcomes for some variables in some studies, they did not consistently demonstrate greater effects for the SI approach over alternative treatments such as the perceptual-motor approach or tutoring. The authors concluded that the SI approach was not effective, suggesting that the gains made were caused by maturation. They did not, however, address the issue of small sample size and low power in regard to the lack of significant findings as an alternative explanation to possible maturational effects. More recently, a systematic review by Baranek (2002) on sensory-based interventions for children with autism concluded that, although the limited studies available on this population specifically addressing the SI approach have suggested positive outcomes, the studies suffered from small samples (most were single-case designs) and weak individual study designs.

Thus, given the limitations of previous reviews in relation to the current research question, and to examine the current body of literature that addresses the SI approach as a coherent whole, 27 individual studies were reviewed, including 13 Level I randomized trials, 5 Level II studies, 3 Level III studies, and 6 Level IV studies. Results are presented by outcome areas, with applicable studies then organized by level of evidence. Outcome areas examined were as follows: motor performance, sensory processing, behavioral outcomes, academic and psycho-educational outcomes, and occupational performance.

Motor Performance

Fourteen articles examined motor outcomes of the SI approach, including component skills such as fine and gross motor skills, as well as general motor planning skills and more functional measures of motor performance and praxis such as participation in gross and fine motor play. Some positive gains were found in 10 of the 14 studies, suggesting that the SI approach is better than no treatment and at least as effective as, and sometimes more effective

than, perceptual-motor treatment in improving aspects of motor performance. The studies also suggested that these gains are maintained after the cessation of intervention. There was considerable variability across studies in the measures used and the type of results found; it appears that gains in praxis and overall motor skills may be most consistently found to occur with the SI approach. However, findings are not conclusive, and generalizability is limited until further research occurs.

Level I Studies. Three studies on children with learning disabilities—Humphries, Wright, McDougall, and Vertes (1990); Humphries, Wright, Snider, and McDougall (1992); and Humphries, Snider, and McDougall (1993)—found that both the SI and perceptual-motor approaches improved motor performance skills better than no intervention. Humphries et al. (1990) found the SI approach produced greater gains than both the perceptual-motor approach and no treatment in overall gross motor skills, bilateral coordination, strength, and motor accuracy and that the SI approach was superior in improving the number of areas of sensory and motor dysfunction. Humphries et al. (1992) documented that the SI approach was more effective than perceptual-motor and no treatment, specifically in motor planning skills but not in other motor skills. The perceptual-motor approach was more effective than the SI approach but no better than no treatment on measures of visual-motor skill and balance. On a measure of bilateral coordination, the perceptual-motor approach was more effective than no treatment but no better than the SI approach. Humphries et al. (1993) concluded that, although the group receiving the SI approach demonstrated improvement in twice as many ratings of severity of dysfunction as the perceptual-motor group, the SI approach was only as effective as the perceptual-motor approach in decreasing the severity and number of symptoms of motor and sensory integrative dysfunction (e.g., bilateral coordination, praxis).

Ziviani, Poulsen, and O'Brien (1982) found the SI approach to be more effective than remedial classroom activities in improving fine motor performance, whereas Werry, Scaletti, and Mills (1990) found that both the SI approach and the no-treatment group improved significantly on motor performance measures. Finally, Wilson and Kaplan (1994) conducted a follow-up study on children with learning disabilities and found that children who received 6 mo of intervention using the SI approach maintained the gains in their gross motor skills 6 mo after the end of intervention.

Level II Studies. Ayres (1977) found no significant difference on a fine motor test of motor accuracy between

a small sample of no-treatment control participants and children with learning disabilities who had received the SI approach. Similar to Humphries et al. (1993), Bullock and Watter (1978) found that the incidence of symptoms of SI dysfunction (e.g., praxis, crossing the midline, skilled activities) and the level of severity of dysfunction of gross motor abilities decreased markedly after 6 mo of intervention using the SI approach. In this study, 86% of school-aged children and 75% of preschool children in the SI approach group demonstrated a decrease in the total number of symptoms of SI dysfunction compared with 7% of school-aged and 14% of preschool-aged children in the control group.

Bundy et al. (2007) examined motor performance and praxis in terms of playfulness. Although they initially anticipated that there would be a significant difference in playfulness scores between children with problems in sensory processing and typically developing no-treatment control participants, initial overall playfulness scores in the treatment group were relatively typical before therapy, suggesting little room for change. However, the study did find that the children with problems in sensory processing were more likely to engage in sedentary play before intervention and showed increased levels of active play after intervention using the SI approach. Similar pattern changes did not occur in the control group.

Level IV Studies. Two single-case studies on children with motor coordination problems found positive results in improved motor performance (Allen & Donald, 1995; Leemrijse et al., 2000) and rhythm (Leemrijse et al., 2000). In addition, one study suggested that the SI approach improves play skills in children with autism (Case-Smith & Bryan, 1999).

Sensory Processing

Thirteen studies of intervention using the SI approach examined outcomes thought to be indicators of improved sensory processing. Seven studies showed positive outcomes, including changes in duration of nystagmus, improvements in tactile function (e.g., tactile discrimination), reports of overall changes in sensory processing (e.g., electrodermal responsivity), and decreases in sensory defensiveness. This review suggested that positive outcomes related to intervention using a SI approach are found in these areas; however, the conclusiveness of results is hampered by the small sample sizes (e.g., groups of 5–18) in all studies except Ottenbacher et al. (1979), resulting in possible underreporting of positive findings.

Level I Studies. Ottenbacher et al. (1979) examined the effect of length of intervention on changes in nystagmus. Although a causal relationship could not be

confirmed, they concluded that longer duration of therapy (e.g., 6 mo vs. 3 mo) was significantly related to increased duration of nystagmus in children with hypnystagmus, thereby suggesting more normalized processing of vestibular stimuli. Moreover, they ruled out maturation as a factor in the increased nystagmus: Older children were not found to have longer nystagmus than younger children at pretest. Carte, Morrison, Sublett, Uemura, and Setrakian (1984) examined changes in nystagmus in children with learning disabilities and found that the intervention that used an SI approach resulted in significant increases in nystagmus duration in children with depressed nystagmus compared with no treatment. Morrison and Sublett (1986) examined changes in nystagmus in children with reading delays and problems with SI and found no significant changes as a result of intervention using the SI approach. More recently, Miller, Coll, et al. (2007) found that occupational therapy using an SI approach (OT/SI) with children with problems in sensory modulation resulted in a greater reduction in the amplitude of electrodermal responses compared with no-treatment and activity groups, indicating a decreased stress response to repetitive and potentially noxious sensory stimuli.

Level II Studies. Schroeder (1982) found tactile discrimination gains, as seen in improved performance on the Manual Form Perception Test (Ayres, 1980), in children receiving intervention using the SI approach. Children who received a combined approach of SI and a perceptual–motor curriculum improved in visual, auditory, and tactile areas. Children who received only the perceptual–motor intervention demonstrated only auditory gains.

Level III Studies. Miller, Schoen, et al. (2007) found significant gains on a parent-reported measure of sensory processing skills after OT/SI with children with problems in sensory processing.

Level IV Studies. Ottenbacher (1982a) found that intervention using the SI approach resulted in increased duration of nystagmus in three children with learning disabilities, whereas Leemrijse et al. (2000) found that using the SI approach improved visual perception in children with developmental coordination disorder.

Behavioral Outcomes

Level I Studies. In the area of behavior, attention, and self-esteem outcomes, Polatajko, Law, Miller, Schaffer, and Macnab (1991) found the SI approach resulted in gains in self-esteem after 6 mo of intervention. These gains were sustained at 3 mo after therapy. However, these gains were not significantly greater than those

demonstrated by the perceptual–motor group. Wilson, Kaplan, Fellowes, Gruchy, and Faris (1992) compared the effect of the SI approach to tutoring and found no differences between interventions, except that the SI group also improved on a measure of attention and maladaptive behaviors, with scores improving from dysfunctional levels to within normal limits after 6 mo of intervention. More recently, Miller, Coll, et al. (2007) found that occupational therapists using the SI approach saw significant gains in attention and cognitive and social skills among children with problems in sensory processing, compared with children who received no treatment and an alternative activity–based treatment group.

Level III Studies. Miller, Schoen, et al. (2007) found significant gains in socialization, and a decrease in internalizing and externalizing behaviors, after occupational therapy using the SI approach with children with problems in sensory processing.

Level IV Studies. Case-Smith and Bryan (1999) and Linderman and Stewart (1999) found that the SI approach improved social interaction and decreased disruptive behaviors in children with autism. Roberts et al. (2007) found increased engagement and decreased aggression in a child with sensory modulation disorder.

Academic and Psychoeducational Outcomes

Twelve studies examined academic and psychoeducational outcomes (e.g., math, reading, visual targeting, cognitive functions, language). Six of these studies suggested some positive gains, particularly that reading skills improve with the SI approach and are maintained at follow-up; however, it is unclear whether these effects are greater than gains achieved by alternative interventions.

Level I Studies. White (1979) and Grimwood and Rutherford (1980) found that the SI approach significantly increased reading skills in children at risk for reading failure and who had problems in SI. Reading performance improved from dysfunctional levels to at or near the level of typically developing peers, and gains in reading accuracy were sustained over a 2-yr follow-up period. Carte et al. (1984) found reading, math, and visual performance on a targeting test improved for children in both the SI approach and the no-intervention groups. They suggested gains may have been caused by maturation but did not account for the poor power of their study caused by small sample size (e.g., groups of 7–15). Similarly, Humphries et al. (1990, 1993) found no significant gains on a variety of psychoeducational variables, reflecting higher cognitive functions, language, and academic skills for any group. Polatajko et al. (1991) found both SI and perceptual–motor approaches were associated with significant gains in

the reading, math, and written language outcomes of children with learning disabilities compared with typical norms and that these changes were sustained at the 9-mo follow-up. There was no significant difference between children who received SI and perceptual–motor approaches, except that math scores were maintained significantly better in the SI group at the 9-mo follow-up.

Level II Studies. Ayres (1972) found that intervention using the SI approach produced significant gains in reading and auditory-language skills in children with learning disabilities compared with a no-treatment control group matched for type and severity of SI problems. Schroeder (1982) found all groups improved similarly in reading and spelling after intervention using the SI approach, a perceptual skills curriculum, and a combination of both approaches. However, children who received the SI approach improved more in math skills.

Occupational Performance Outcomes

Three recent studies examined changes in individualized goals measuring functional occupational performance changes (e.g., goal attainment scaling), such as improved sleep patterns, increased repertoire of foods eaten, improved ability to participate in mealtime and homework activities, improved ability to manipulate fasteners, or improved ability to pump a swing. All studies demonstrated significant gains in self-identified tasks and activities, and positive changes were reported in both the performance of tasks and the satisfaction of performance of tasks.

Level I Studies. Miller, Coll, et al. (2007) reported that occupational therapy using the SI approach resulted in significantly greater improvements in individual functional goals than no treatment or an alternative activity-based intervention in children with problems in sensory processing.

Level III Studies. Candler (2003) documented significant improvement in performance or satisfaction on individualized family-developed functional goals after an SI-based summer program for children with problems in sensory modulation. Miller, Schoen, et al. (2007) also found significant gains on functional, parent-developed goals after occupational therapy using the SI approach with these children.

Level IV Studies. Roberts et al. (2007) documented gains in individualized functional, behavioral, and attention goals in a child with problems in sensory modulation.

Limitations and Critique

These studies reflect research that spans a period of more than 37 yr, during which expectations for scientific rigor

and detail of reporting have evolved. All studies reviewed had some methodological problems, although more recent studies, at various levels of scientific inquiry (Miller, Coll, et al., 2007; Miller, Schoen, et al., 2007; Roberts et al., 2007), not only demonstrated good scientific rigor but also addressed the limitations discussed here. Some studies did not have independent evaluators (e.g., Bullock & Watter, 1978; Werry et al., 1990), and others did not report the qualifications of the evaluators or the treating therapists (e.g., Morrison & Sublett, 1986; Schroeder, 1982). In addition, potentially inappropriate evaluators were used in some studies: Grimwood and Rutherford (1980) used psychology students as examiners, and it is unclear whether the examiners administered standardized tests of SI or only educational tests. Polatajko et al. (1991) used a research assistant who was not an occupational therapist to administer evaluations. On average, however, all studies reviewed demonstrated at least a moderate degree of scientific rigor on the basis of performance in the 24 components identified by MacDermid (2004) for rating the quality of research studies (see Table 1). In addition to these common methodological problems, six major limitations are highlighted and discussed in the following sections: (1) control for developmental maturation effects, (2) characteristics of the sample population, (3) statistical power and effect sizes, (4) dosing of intervention, (5) selection of outcome measures, and (6) manualization and fidelity to intervention.

Control for Developmental Maturation Effects

A limitation often reported in the studies reviewed was whether results were a factor of normal development or maturation rather than of the intervention provided. This concern is typically controlled for by the use of a no-treatment control group or an alternative intervention. Thirteen Level I and 4 Level II studies adequately controlled for maturation effects. Fourteen studies used no-treatment groups, and 5 studies used groups that provided an alternative nonsensorimotor intervention as an active placebo to control for maturation as well as for Hawthorne effects. An additional 4 studies used an alternative perceptual-motor intervention. With this level of control, there should be no issue regarding the influence of maturation on significant outcomes, although the influence of Hawthorne effects may be inconclusive. Hoehn and Baumeister (1994) argued that although many studies they reviewed had positive time effects for intervention using an SI approach (e.g., gains were made from pretest to posttest), because these gains were not always greater than no treatment or alternative treatments, maturation effects could not be ruled out. Although this is a legitimate argument, the lack of

statistical power in nearly every study makes it more likely that the failure to achieve significant difference from alternative groups is caused by a Type II error rather than maturation, especially given the moderate effect sizes of many outcomes.

Characteristics of the Sample Populations

With regard to participant selection, all studies contained clear inclusion criteria; however, most studies used a sample of convenience, especially for control groups. In some cases, multiple sites were used, which strengthened the participant selection (e.g., White, 1979). Another problem with participant selection was the frequent heterogeneity of the population both within and across studies. Within individual studies, early studies generally identified children with learning disabilities and then further identified problems in SI, usually using a standardized test of SI with no specifics on the dysfunctional subtype. Later studies examined more homogeneous populations but focused almost exclusively on children with vestibular processing problems, typically a milder dysfunction. Children with dyspraxia were almost never specifically identified. More recent studies have attempted to include more homogeneous populations, such as children with problems in sensory modulation (Miller, Coll, et al., 2007; Miller, Schoen, et al., 2007). This diversity in the study populations may lead to variability in responses and large standard deviations as well as inconsistent outcomes across studies, which can decrease the ability to find significant results (see Table 1).

Statistical Power and Effect Sizes

A major limitation of the studies examining the SI approach to date has been the use of small sample sizes, resulting in low statistical power and a general trend for Type II errors (e.g., rejecting a positive result because of nonsignificance when there is in fact a true positive result). Within the Level I, II, and III studies, 21 studies had groups with an average sample size of 22 participants. In some cases, authors reported larger sample sizes but then subdivided the groups, resulting in analyses being conducted on groups of ≤ 15 participants (e.g., Carte et al., 1984; Werry et al., 1990). In other cases, loss of participants was reported, resulting in small sample sizes becoming even smaller (e.g., Wilson & Kaplan, 1994); in one case, this situation resulted in the loss of an adequate control group (e.g., Polatajko et al., 1991). The 15 studies reporting on no-treatment control groups had an average group size of 19. The 4 studies reporting on alternative perceptual-motor treatment had an average group size of 28, and the 5 studies that had placebo alternative

treatments had an average of 10 participants. In all, 12 of the 21 studies reviewed conducted analyses on <20 participants. The range of group sizes for all studies was 5–78 participants, with only 1 study, Bullock and Watter (1978), having a sample size >43 (see Table 1).

On average, given these sample sizes, the power of any of these studies to detect significance with a medium effect size of 0.50 was approximately 0.40 at best and 0.15 at the worst. The generally accepted minimum level of power in a study is 0.80, which would require 65 participants in each group to detect a medium effect. The result of this low power in most of the studies reviewed is that significance was generally found only for large effects and was not often found for moderate to small effects. Effect size, primarily reported as Cohen's d , is a measure of the difference between performances of two groups and reflects the magnitude of a treatment effect. Effect sizes at posttest, which reached significance at the .05 level, ranged from $d = 0.23$ to 6.26, with an average effect of $d = 2.76$, a very large effect. Effect sizes for outcomes that were positive for the experimental variable, but not significantly different from the alternative group, ranged from $d = 0.0$ to 4.14 with an average of $d = 0.45$, which is considered to be a robust medium effect capable of detecting observable change in the participant (Cohen, 1977). However, low power resulted in several studies determining that the SI approach was less effective than no treatment or alternative treatment on some variables across all outcome categories but most commonly in motor and academic/psychoeducational areas. Thus, the literature reviewed demonstrates real limitations with regard to Type II errors, which likely resulted in under-reporting of significant positive treatment effects.

Dosing of Intervention

Another major concern in reviewing the whole body of research literature on the SI approach is that the frequency, duration, and amount of intervention varied greatly from one study to another. Among the Level I, II, and III studies, the hours of reported intervention ranged from 13 (Werry et al., 1990) to 72 (Humphries et al., 1992, 1993), with an average of 36 hr per study. Level IV studies provided as little as 5 hr of intervention (Case-Smith & Bryan, 1999) and as many as 50 hr (Ottenbacher, 1982a), making comparison of dosage effectiveness across studies difficult. Frequency of intervention ranged from 1 to 5 times per wk, with the average being 2 to 3 times per wk. Length of the sessions varied from 30 to 60 min, with 60-min sessions being the most prevalent. Total duration of the studies varied from 10 wk to 1 yr. This variability in the amount of intervention provided, in conjunction with

power issues, makes it difficult to determine whether lack of significant effects are caused by only poor power, a lack of an adequate amount of intervention to effect change on selected outcome measures, or a combination of both problems.

Selection of Outcome Measures

The measures used to document outcomes varied greatly across studies and included at least 122 different outcome measures, including individual subtests of various test batteries. Outcome measures varied greatly in number and type of outcomes examined per study, which has implications for power to detect positive outcomes, especially when viewed in light of small sample sizes. Some studies had many variables but small sample sizes for the number of variables analyzed: Humphries et al. (1992, 1993) had 53 variables for groups of 35, Wilson et al. (1992) had 19 variables with groups of 11–15, Carte et al. (1984) had 12 variables with groups of 7–15, and Humphries et al. (1990) had 20 variables with groups of 10. The use of post hoc correction for multiple measures would limit the possibility of detecting significance to only very large intervention effects, thus contributing to additional Type II errors.

Nearly all outcomes were component based and not based on occupational performance or participation. The most frequently used outcomes (in eight studies each) were postrotary nystagmus tests and various components and subtests of the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978). The Wide Range Achievement Test (Jastak & Jastak, 1978) was used in five studies, the Southern California Sensory Integration Tests (Ayres, 1980) or Sensory Integration and Praxis Tests (Ayres, 1989) were used in five studies, and the Woodcock–Johnson Psycho-Educational Battery (Woodcock & Johnson, 1977) was used in three studies. Intelligence measures were used in three studies (Humphries et al., 1990, 1992, 1993). In reviewing these outcomes, a question might be why measures such as IQ tests would be used instead of more functionally based outcome measures. In addition, although component-based measures such as postrotary nystagmus testing may provide meaningful clinical information, they are not the best measures of the meaningful and relevant changes of intervention valued by our clients and families.

Manualization and Fidelity to Intervention

Many studies did not provide a complete description of the intervention provided, a measure of adherence to the SI approach principles, or a fidelity instrument for alternative interventions; these methodological limitations

have been previously reviewed (Parham et al., 2007). Only three authors in a total of seven studies reported using some type of manual for intervention or fidelity check for adherence to intervention (Bundy et al., 2007; Humphries et al., 1990, 1992, 1993; Miller, Coll, et al., 2007; Miller, Schoen, et al., 2007; Polatajko et al., 1991). In some cases, however, these authors attempted to control the intervention to such an extent (e.g., adhering to a list of predesignated activities; Humphries et al., 1990), that they violated some of the core concepts of the SI approach. In the studies developed by Humphries et al. (1990, 1992) and Polatajko et al. (1991), the protocols did not fully reflect clinical practice. For example, in these studies therapists in the SI group were permitted to do only sensory-based activities and could not engage the children in activities such as throwing bean bags at a target while on a swing to elicit higher-level adaptive responses, which are core to the SI approach (Bundy, Lane, & Murray, 2002; E. Yack, personal communication, June 11, 2009). Wilson and Kaplan (1994) also specifically excluded such eye–hand coordination activities from the SI approach group. Given the issues with fidelity of intervention, the use of the perceptual–motor approach as a comparison intervention is questionable. Both interventions would be expected to make sensorimotor changes, and both provided aspects of sensory input. The lack of clear definition of the two interventions and the inability to fully provide the SI approach in its intended manner may contribute to the smaller effect size differences between these interventions.

Discussion and Implications for Practice, Education, and Research

For clinicians, educators, and researchers, several factors are important in developing evidence-based practice and in reviewing evidence-based literature. Traditional methods focus solely on whether statistical analyses yield significant outcomes in analyzing studies. Alternatively, other well-respected behavioral researchers have long suggested that it is critical to consider power and effect size in addition to sample size when examining research evidence (Rosenthal & Rosnow, 1991; Tickle-Degnen, 1988). Statistical significance indicates only that a given result is likely to not occur by chance, whereas effect sizes reflect the magnitude of the clinical effect; thus, examination of the effects of an outcome is likely to yield more clinically relevant information for the occupational therapy practitioner. Unfortunately, examination of research in this manner has not been part of the tradition in re-

views regarding the SI approach—a problem that has also been identified in other disciplines (Jacobson & Truax, 1991).

For clinicians, this review provides a comprehensive review of the research evidence on the SI approach. It is unique in that it independently examines all research articles and does not depend on interpretations by previous reviewers. Findings suggest that there is a trend for positive results from the SI approach, especially in contrast to no treatment. Consistency of findings is limited by a variety of methodological concerns, but given the large effects of positive results, occupational therapists can use this information to begin to support the use of the SI approach within their professional domain of practice with a variety of outcomes, particularly sensory and motor outcomes and individually identified client-centered goals.

With regard to implications of these findings for theory and research development, Tickle-Degnen (1988) suggested that in the development of a new theory and its intervention, research studies should proceed from assessing whether the intervention is effective to how it is effective. Research should then look for modifying factors that influence effectiveness, such as qualities of the child, the therapist, or the environment; last, it should address mediating factors that account for the effectiveness of therapy. Therefore, this approach leads us to the examination of (1) intervention effects and the factors influencing them, (2) the importance of sustainability of achieved gains, (3) the appropriateness of comparison between the SI and perceptual–motor approaches, and (4) the use of client-focused versus occupation- or participation-focused goals.

In reviewing the first of these four factors, development and use of a fidelity measure to ensure the adherence to Ayres' SI intervention principles is critical. This adherence is especially important when researching an intervention that is a blend of art and science and at its core is individualized for and responsive to the client's needs throughout each session (Parham et al., 2007). Although some studies within this review have made attempts to provide information on adherence to theoretical principles and have indicated how they have manualized the intervention, only one of the published studies to date (Miller, Coll, et al., 2007) has identified adherence to all 10 principles (Parham et al., 2007). In some studies, the design has violated those principles despite stating that the study was to assess the effectiveness of the SI approach. When comparing two similar interventions, it is critical that there be fidelity measures and intervention manuals for both approaches.

In addition, the variability in the frequency, length, and duration of intervention is a potential confound for interpreting efficacy. Without clear information in this area, the occupational therapy practitioner will not know how much gain may be expected in a given amount of time. Conversely, in research, clinical experience must guide the dosage decisions in selecting daily amount, weekly frequency, and length of the intervention study to ensure that there is sufficient intervention to provide a measurable change for the outcomes selected. The studies that have shown effective results indicate that therapy 2 to 3 times per wk for 6 mo is commonly an effective frequency, but the total number of hours of therapy may vary depending on the type of outcome being measured. If the outcome is client focused and aimed at affecting core body functions, fewer sessions may be required before observing gains. If the outcome is focused on a complex level of participation, which may be reliant on first addressing several underlying skills, a longer period of intervention may be needed.

Some evidence for determining meaningful dosage rates for future studies may be obtained from studies that examined maintenance of gains over time. If we are truly assisting clients in developing occupation, we need to be assured that gains are sustained. In one study, positive gross motor gains were sustained for 2 yr after the end of 62.5 hr of intervention using the SI approach (Wilson & Kaplan, 1994). Similarly, reading gains were sustained at 1 and 2 yr after 24 hr of intervention (White, 1979). Another study reported that 24 hr of intervention using the SI approach resulted in improvements in self-esteem, which were maintained for 3 mo after cessation of therapy (Polatajko et al., 1991). Although findings are limited, when comparing the SI approach to tutoring and perceptual–motor approaches, the SI approach is the only one that produced any sustained outcomes. For clinicians, this finding may highlight the importance within SI theory of working from a developmental and neurological perspective to address the sensory contributions to motor coordination; motor planning; and other perceptual, social emotional, and cognitive skills. Moreover, this finding highlights the importance of allowing a foundation to be established for typical development to then further unfold.

The strongest significant effect sizes were with motor skills and Goal Attainment Scaling (GAS; Kiresuk, Smith, & Cardillo, 1994), an assessment measure developed with the client or parents to measure improvements across all areas of functioning from client-centered goals to participation goals. GAS is designed to set goals for a designated time period and can be customized to reflect gains predicted to occur during the intervention period.

GAS may allow us to measure the most important outcomes to our clients while also providing sufficient effect sizes to produce statistically significant evidence of improvement and positive change, even when sample sizes limit the power of a study. Ironically, although the focus of this review was to systematically review the effectiveness of the SI approach on the ability of children and adolescents with problems in SI and sensory processing to engage in desired occupations, only a handful of studies addressed occupation such as play preferences (Bundy et al., 2007), individualized functional goals, and satisfaction in task performance (Candler, 2003; Miller, Schoen, et al., 2007). It appears that although many researchers have focused on using outcome measures designed for initial assessments of problems, we have not fully drawn from the core of our professional knowledge, steeped in understanding and appreciation of occupation, in designing outcome measures.

Last, educators should teach occupational therapy students how to assess the quality of efficacy research, not only for traditional methodological concerns but also for aspects highlighted in this review as well as those exposed by Tickle-Degnan (1988) and Miller, Schoen, et al. (2007). Occupational therapy practitioners need to assess efficacy research not just from the perspective of *whether* it is effective but also from the perspective of *how* it is effective. This paradigm shift in examination of research evidence can guide our practice as well as future research endeavors.

Conclusions

This synthesis of the evidence suggests that the SI approach may result in positive outcomes in the areas of sensorimotor skills and motor planning; socialization, attention, and behavioral regulation; reading and reading-related skills; and individualized goals for the study populations. Various outcomes related to the SI approach were better than the outcomes associated with the no-treatment control condition in more than half of the studies reviewed and were just as effective (although not better) than alternative treatments including perceptual–motor-based therapies and tutoring–academic-based interventions for some outcomes in some studies. In addition, although limited, only the SI approach, compared with perceptual–motor treatment and tutoring, showed any sustainable gains after intervention in the studies in this review. Results for specific outcomes varied among studies, and intervention effects also varied from small to large. Recent studies have shown positive trends supporting the effectiveness of the SI approach, especially when measuring

goals customized for the client. This review suggests that, despite low power in most studies, there is a trend toward positive evidence to support the SI approach.

Further research addressing the limitations noted previously is needed to support the conclusiveness of these results. A meta-analysis and further examination of mediating factors on intervention effects is recommended. In addition, more qualitative studies that examine the occupational performance and participation outcomes valued by our families are needed (Cohn & Cermak, 1998). For clinicians, intervention planning for individual clients requires the review of both quantitative and qualitative study results and then the integration of that information with specific knowledge of the client's needs, expert consensus within the field, and professional judgment. Occupational therapy practitioners, researchers, and educators can best help clients and their families when all levels of evidence are considered in evidence-based practice. ▲

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