

Sensory-Based Intervention for Children with Behavioral Problems: A Systematic Review

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Abstract Sensory-based intervention is a common approach used to address behavioral problems in children. Types of sensory-based intervention for children and details of the intervention effectiveness have not been systematically examined. This review examined the effectiveness and ideal types of sensory-based interventions for children with behavioral problems. Searching seven databases, a total of 132 studies were identified; 14 met the selection criteria and were reviewed. Seven of the studies were tactile-based interventions, four were proprioceptive-based intervention and three were vestibular-based interventions. Tactile-based interventions such as massage therapy were the most promising intervention in reducing behavioral problems. However, evidence concerning the effectiveness of sensory-based interventions remains unclear. More research is required for determining the appropriate intervention for children with behavioral problems.

Keywords Sensory-based intervention · Tactile · Proprioceptive · Vestibular · Children · Behavioral problems

Introduction

Behavioral problems are a core issue managed by rehabilitation therapists who work with children with developmental disabilities (Smith et al. 2005). Children with various clinical conditions including autism spectrum disorders (ASD), attention deficits hyperactive disorders (ADHD), cerebral palsy, down syndrome, and certain intellectual disabilities have been reported to exhibit behavioral problems that include inattention, temper tantrums, aggression, self-injurious behaviors, and repetitive and stereotyped behaviors (Densem et al. 1989; Mauer 1999; Olson and Moulton 2004; World Health Association 1993).

It is proposed that behavioral problems in children are linked to dysfunctions in sensory processing (Ayres 1991). Sensory processing is necessary to receive, modulate, integrate and organize sensations received in the central nervous system to produce appropriate behavioral responses (Bundy et al. 2002). Dysfunction in sensory processing can therefore impede a child's ability to interpret sensory information with the correct intensity, regulate or organize behavioral responses to participate appropriately in school, social and daily activities (Miller et al. 2007). Instead, children may tend to display avoidance or sensory seeking behaviors (Ben-Sasson et al. 2009). In turn, these inappropriate behavioral responses can detrimentally effect skill development, social relationships with friends, meeting biological needs (Jasmin et al. 2009; Lane et al. 2010; Parham and Mailloux 2005).

Sensory-based interventions (SBI) are a common rehabilitation approach to address behavioral problems caused by dysfunction in sensory processing (Ayres 1991; Case-Smith and Arbesman 2008). SBI use discrete sensory experiences or environmental modifications to facilitate

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regulation of behaviors. In doing so, it assists children to engage appropriately in learning activities (Tomchek and Case-Smith 2009; Watling et al. 2011). This approach primarily includes tactile, proprioceptive, and/or vestibular stimulations. Tactile stimulation provides a touch sensation given by different environment and object qualities. Different forms of touch sensation could include a cold, hot, pain, soft or hard feeling. Proprioception stimulation offers a sensation when muscles and joints are activated by movements and muscle contractions. Vestibular stimulation is provided when an individual is moved in a certain speed and direction. It is related to one's balance when the inner ear of an individual is stimulated by different forms of head movements (Baskaran 2013; Bundy et al. 2002).

Similar to SBI, sensory integration therapy (SIT) refers to intervention using play as the therapeutic medium. Instead of using discrete sensory stimulations, SIT includes the use of a variety of sensory stimulations to enhance the child's ability.

While SBI have been widely used in clinical practice for children with behavioral problems, current research is inconclusive, as numerous studies have produced contrasting results. For example, in a sample of 42 children with ASD, SBI were reported to be effective in managing irritability, lethargy, stereotypic behaviors, hyperactivity, expressive language skills, motor skills and verbal praxis/motor planning skills (Gabriels et al. 2012). In contrast, in a sample of four children with ASD, SBI were not effective in managing inattention, arousal, or hyperactivity in children (Van Rie and Heflin 2009).

Four previous systematic reviews (Case-Smith et al. 2015; Lang et al. 2012; May-Benson and Koomar 2010; Polatajko and Cantin 2010) have analyzed the effectiveness of both SBI and sensory integration or sensory integration interventions alone for children with general sensory processing problems. In the most recent systematic review, 14 of the included 19 studies included SBI, and confirmed mixed results surrounding the effectiveness of SBI towards children with ASD (Case-Smith et al. 2015). Limitations of the studies include low level study design and small sample sizes from $n = 1-10$. In addition, the study did not specifically mention the type of behavior being examined. Consequently, no clear conclusion can be drawn on the effectiveness of SBI on managing children's behavioral problems. In 2012, a review of 25 studies including 17 utilizing SBI for children with ASD (Lang et al. 2012) reported the majority identified no benefits with three studies demonstrating mixed results. Methodological limitations of studies included a lack of fidelity to intervention, incomplete description of the intervention used and heterogeneous sample used. In the third systematic review (May-Benson and Koomar 2010), 27 studies investigated the effectiveness of sensory integration interventions in children with difficulty in processing and integrating sensory

information. Positive changes in sensorimotor, motor planning, socialization, behavior, play, and self-selected goals were found. Limitations included small sample sizes, heterogeneity of the sample and intervention not specifically designed for children with behavioral problems. The fourth review (Polatajko and Cantin 2010) summarized 21 studies on the effectiveness of occupational therapy interventions in children with difficulty in processing and integrating sensory information. Eight studies included either SBI or sensory integration interventions. Due to the heterogeneity relative to the small number of the studies, the effectiveness of SBI or sensory integration interventions was inconclusive. While these systematic reviews demonstrated mixed results around sensory integration interventions, study populations may not be representative as they did not specifically target behavioral problems.

As dysfunction in sensory processing may lead to behavioral problems that interfere with school participation, as well as social and daily activities, SBI is designed to remediate these behavioral problems and thus improve one's function. To date, no systematic review has analyzed SBI for children using behavioral problems as the outcome. The current systematic review will therefore focus on understanding the effectiveness of SBI on targeted behavioral problems and function in school participation, social, and daily activities. This will be the first systematic review to analyze SBI only among children with behavioral problems. Such behavioral problems include attention deficits, temper tantrums, and aggression or self-injurious behaviors, repetitive and stereotyped behaviors, emotional problems of anxiety, restlessness, depression, mood changes, sleep problems and disturbances (Bagatell et al. 2010; Collins and Dworkin 2011; Davis et al. 2011; Escalona et al. 2001; Fertel-Daly et al. 2001; Field et al. 1992, 1997; Hodgetts et al. 2011a, b; Jenkins and Reed 2013; Khilnani et al. 2003; Piravej et al. 2009; Silva et al. 2009; Umeda and Deitz 2011). Recommendations for the types, intensity, and duration of stimulations and their benefits in reducing behavioral problems in children also require investigation as current recommendations are broad and inconsistent with limited evidence in the literature.

The objectives of this current systematic review will examine the clinical evidence of SBI surrounding children with behavioral problems, and in the event of clinical evidence, determine best types of stimulation and intensity of SBI.

Method

Literature Search

An extensive literature search was conducted to locate published studies documenting SBI for children with

behavioral problems. Keyword searches were performed in seven chosen databases. These were Medline, PubMed, Embase, PsycINFO, CINAHL, OT Seeker and the Cochrane Library. The following keywords were used: sensory integration, sensory stimulation, SBI, children, adolescent, behavior, stereotypical, aggressive, tantrum, hyperactive. Boolean operators ‘OR’, ‘*’, ‘AND’ were also used to capture potential studies. A hand-search of relevant journal article reference lists was also conducted to identify additional studies.

Inclusion and Exclusion Criteria

In order to be included in this review, studies were required to meet the following inclusion criteria.

- Participants: children or adolescents between 2 and 19 years of age with behavioral problems including inattention, temper tantrums, and aggression or self-injurious behaviors, repetitive and stereotyped behaviors, restlessness (Olson and Moulton 2004; World Health Association 1993).
- Interventions: SBIs, or sensory stimulation or interventions which provided “proprioceptive” or “vestibular” or “tactile” stimulations.
- Outcome measures: examined outcomes in behaviors and school participation, social or daily activities.
- Study designs: rated as level 3 (case-control/single-case studies) or higher (cohort or randomized control trials according to the Centre for Evidence Based Medicine (CEBM 2009) hierarchy of studies.

Studies were excluded if the type of stimulations offered in the intervention was not specified, they were not published in English language or were published before the year 1990.

Data Extraction, Quality Assessment

Two independent reviewers (F.W.Y. and K.P.Y.L.) completed screening and selection of the retrieved studies, and assessed the methodological quality and extracted data. The data from the selected studies was extracted according to the title, participants recruited, outcome measures and interventions used. The two independent reviewers (F.W.Y. and K.P.Y.L.) also classified the interventions into tactile, proprioceptive and/or vestibular stimulations according to the study description and the definition as described above. The Physiotherapy Evidence Database (PEDro) scale (Moseley et al. 2002) was used to assess the methodological quality of the randomized control trials. The PEDro assesses the study on a ten point scale examining 11 criteria including blinding methods, randomization procedures, outcome measures appropriateness of data

and analysis and intention to treat. The PEDro scale rates 9–10 as excellent quality, 6–8 as good quality, 4 or 5 as fair quality, and below 4 as poor quality. The single-subject research design (SSRD; Logan et al. 2008) was used to assess the methodological quality of the single-subject designs studies. The SSRD consists of 14-point scale with scores between 11 and 14 considered strong; scores between 7 and 10 considered moderate and scores <7 considered weak. In the event of disagreement between reviewers, consensus would be sought from a third reviewer, however this was not required.

Results

Study Identification

The search strategy and hand searching identified 132 studies for review. After implementation of the inclusion and exclusion criteria, 14 studies remained. This process is specified in Fig. 1. From the 14 studies, six were prospective randomized controlled trials (RCTs), and eight were single-case designs. Studies included in this systematic review were reported based on the preferred reporting items for systematic review and meta-analysis PRISMA flow diagram (Moher et al. 2009; Fig. 1). Meta-analysis for the RCTs study could not be conducted due to study heterogeneity and different concepts of outcome measures used. A narrative synthesis was conducted instead.

Methodological Quality Assessment of Studies

According to the scoring of the PEDro scale, two RCTs were rated as excellent, scoring 9 out of 10 (Escalona et al. 2001; Khilnani et al. 2003). The remaining four RCTs had a rating of good; two with a score of 8 (Field et al. 1992, 1997) and two a score of 7 (Piravej et al. 2009; Silva et al. 2009). The details of the scoring for each study are presented in Table 1.

Using the SSRD, six out of eight studies with a single-case design scored 11 suggesting a strong methodological quality (Bagatell et al. 2010; Collins and Dworkin 2011; Fertel-Daly et al. 2001; Hodgetts et al. 2011b; Jenkins and Reed 2013; Umeda and Deitz 2011). The remaining two studies obtained a score of 10, consistent with moderate quality (Davis et al. 2011; Hodgetts et al. 2011a). This analysis is presented in Table 2.

Summary of Study Details

Details of the 14 included studies are presented in Table 3. This table summarizes study details including (a) objectives; (b) diagnosis of participants; (c) number of

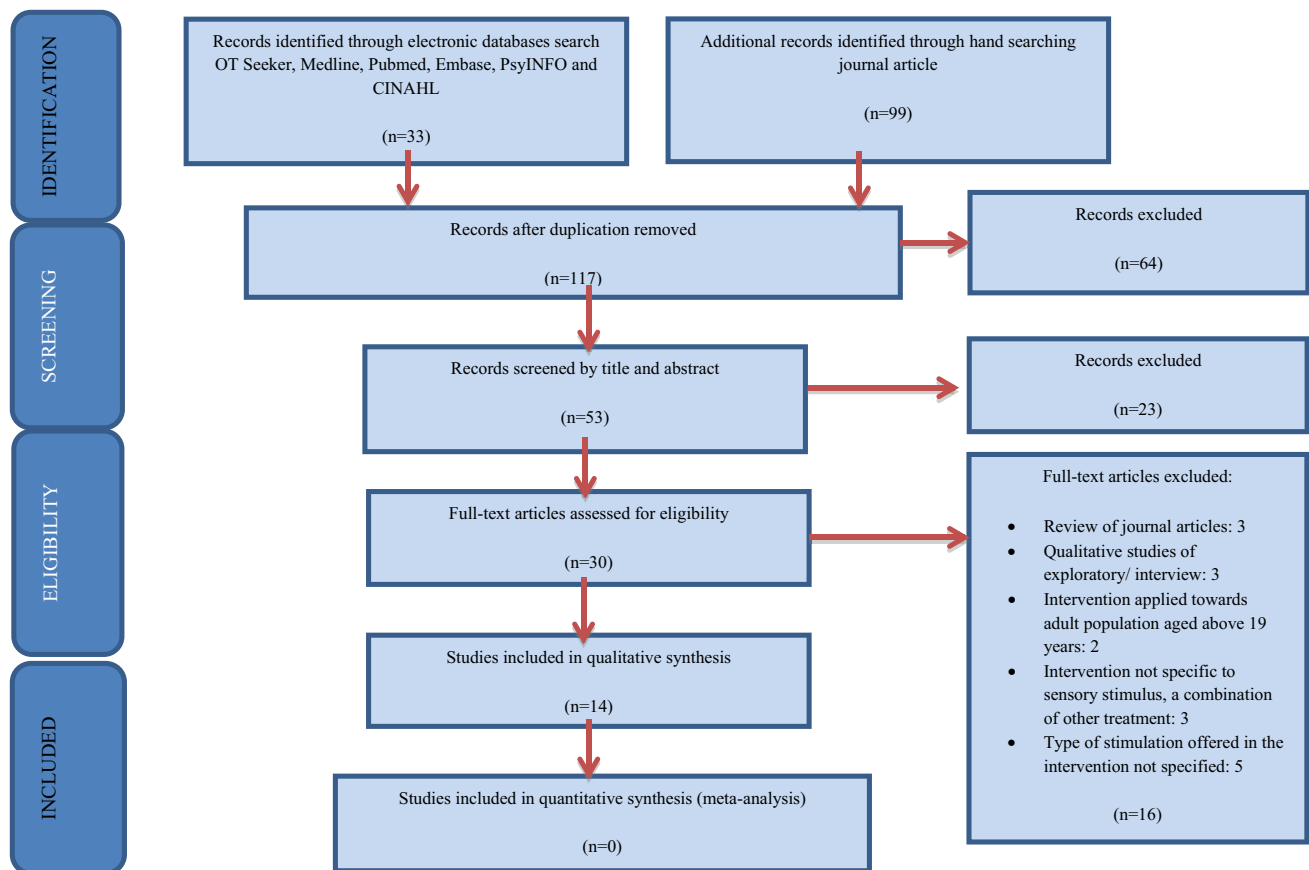


Fig. 1 Flow chart of search strategy based on PRISMA flow diagram

participants; (d) age group of participants; (e) outcome measures; (f) intervention(s) applied; and (g) intervention outcomes.

Participants

The 14 studies involved 298 individuals with various diagnoses. The majority of participants were diagnosed with ASD ($n = 180$; 60.4 %) (Bagatell et al. 2010; Davis et al. 2011; Escalona et al. 2001; Field et al. 1997; Hodgetts et al. 2011a, b; Jenkins and Reed 2013; Piravej et al. 2009; Silva et al. 2009; Umeda and Deitz 2011); followed by depression and adjustment disorders ($n = 72$; 24.2 %) (Field et al. 1992); ADHD ($n = 31$; 10.4 %) (Collins and Dworkin 2011; Khilnani et al. 2003); attention difficulties ($n = 10$; 3.3 %) (Collins and Dworkin 2011); and pervasive developmental disorders (PDD) ($n = 5$; 1.7 %) (Fertel-Daly et al. 2001). Participants ranged in age from 2 to 19 years, with 213 males (71 %) and 85 females (29 %). The targeted behaviors in each study have been summarized in Table 4.

Intervention

Tactile, proprioceptive, or vestibular sensory stimulations were used as the SBI described in the selected studies. The majority of interventions evaluated the efficacy of tactile stimulation in children with behavioral problems ($n = 7$) (Davis et al. 2011; Escalona et al. 2001; Field et al. 1992, 1997; Khilnani et al. 2003; Piravej et al. 2009; Silva et al. 2009), followed by proprioceptive stimulation ($n = 4$) (Collins and Dworkin 2011; Fertel-Daly et al. 2001; Hodgetts et al. 2011a, b), and vestibular stimulation ($n = 3$) (Bagatell et al. 2010; Jenkins and Reed 2013; Umeda and Deitz 2011).

Tactile-Based Intervention

Six of the seven studies utilizing tactile stimulations were RCTs (Escalona et al. 2001; Field et al. 1992, 1997; Khilnani et al. 2003; Piravej et al. 2009; Silva et al. 2009) with one a single-subject design (Davis et al. 2011). The specific tactile-based interventions were massage therapy, touch therapy and brushing. Targeted behaviors were

Table 1 The Physiotherapy Evidence Database (PEDro) scale result

Questions	Escalona et al. (2001)	Khilnani et al. (2003)	Field et al. (1992)	Field et al. (1997)	Piravej et al. (2009)	Silva et al. (2009)
1. Eligibility criteria were specified	1	1	1	1	1	1
2. Subjects were randomly allocated to groups	1	1	1	1	1	1
3. Allocation was concealed	1	1	0	0	0	1
4. The groups were similar at baseline regarding the most important prognostic indicators	1	1	0	0	0	1
5. There was blinding of all subjects	1	1	1	1	1	0
6. There was blinding of all therapists who administered the therapy	0	0	1	1	1	0
7. There was blinding of all assessors who measured at least one key outcome	1	1	1	1	0	0
8. Measures of at least one key outcome were obtained from more than 85 % of the subjects initially allocated to groups	1	1	1	1	1	1
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by “intention to treat”	1	1	1	1	1	1
10. The results of between-group statistical comparisons are reported for at least one key outcome	1	1	1	1	1	1
11. The study provides both point measures and measures of variability for at least one key outcome	1	1	1	1	1	1
Total score	10	10	9	9	8	8

The study obtained a score of 1 if it fulfilled the questions stated

generally consistent in all studies including stereotypical behaviors (hand flapping, body rocking, fingers flickering, fidgety), hyperactivity, inattentiveness, impulsive, restlessness, anxiety, and sleep disturbances. Most tactile-based interventions included massage therapy (Escalona et al. 2001; Field et al. 1992; Khilnani et al. 2003; Piravej et al. 2009; Silva et al. 2009), with two studies using touch therapy (Field et al. 1997), and brushing (Davis et al. 2011).

Massage therapy, used in four of the five studies, reported reduction in targeted behavioral problems in children (Escalona et al. 2001; Field et al. 1992; Khilnani et al. 2003; Silva et al. 2009). Piravej et al. (2009) reported mixed results, indicating a statistical improvement in hyperactivity, inattention measured by the Conners’ Teacher Questionnaire and only anxiety as measured by the Conners’ Parents Questionnaire. Based on the findings of the studies, massage therapy with moderate pressure was applied to the participants (Escalona et al. 2001; Field et al. 1992, 1997; Khilnani et al. 2003). Participants were fully dressed when massage therapy was applied. The sequence of massage started from head/neck, arms, torso, legs, and back. A full application of massage procedures can be found in the study by Field et al. (1997). The procedure covers in detail how many strokes are needed to apply massage in each body part and the positions that the child needs to be during the massage session. Most of the studies

used massage therapy during mid-afternoon (Field et al. 1992, 1997; Khilnani et al. 2003) and one used it prior to bedtime (Escalona et al. 2001). The duration of the massage therapy varied from 15 to 30 min a day with the intervention ranging from 5 days to 5 months. Escalona et al. (2001) and Field et al. (1997) suggested 15 min per day for a 1 month duration. Khilnani et al. (2003) suggested 20 min per week of massage for 1 month’s duration, with a total of nine sessions. Field et al. (1992) suggested 30 min massage per day for the shortest duration of 5 days. Silva et al. (2009) suggested a total of 5 month’s duration, which was the longest duration of all. Touch therapy improved children’s inattention issue in the classroom as well as increasing their ability to socialize (Field et al. 1997). Brushing, on the other hand, reported no benefit on the level of stereotypical behaviors (Davis et al. 2011). In addition, no reports were found in increasing school, daily livings and social participation with brushing.

Overall massage therapy provided the strongest positive evidence for the benefit of using tactile stimulation in the SBI.

Proprioceptive-Based Intervention

Four studies used proprioceptive stimulation, specifically weighted vests, within a single-subject design methodology (Collins and Dworkin 2011; Fertel-Daly et al. 2001;

Table 2 The single-subject research design (SSRD) result

Questions	Collins and Dworkin (2011)	Hodgetts et al. (2011a)	Bagatell et al. (2010)	Davis et al. (2011)	Fertel-Daly et al. (2001)	Hodgetts et al. (2011b)	Jenkins and Reed (2013)	Umeda and Deitz (2011)
1. The participant(s) was/were sufficiently well described to allow comparison with other studies or with the reader's own patient population	1	1	1	1	1	1	1	1
2. The independent variables were operationally defined to allow replication	1	1	1	1	1	1	1	1
3. Intervention conditions were operationally defined to allow replication	1	1	1	1	1	1	1	1
4. The dependent variables were operationally defined as dependent measures	1	1	1	1	1	1	1	1
5. Interrater or intrarater reliability of the dependent measures assessed before and during each phase of the study	0	1	0	1	0	1	1	1
6. The outcome assessor was unaware of the phase of the study (intervention vs control) in which the participant was involved	1	1	0	0	0	1	0	1
7. Stability of the data was demonstrated in baseline, namely lack of variability or a trend opposite to the direction one would expect after application of the intervention	1	1	1	1	1	1	1	1
8. The type of SSRD was clearly and correctly stated, for example A–B, multiple baseline across subjects	1	0	1	1	1	1	1	1
9. There was an adequate number of data points in each phase (minimum of five) for each participant	0	1	1	1	1	1	0	1
10. The effects of the intervention replicated across three or more subjects	1	1	1	0	1	1	1	0
11. The authors conducted and reported appropriate visual analysis, for example, level, trend, and variability	1	0	1	1	1	1	1	1
12. The graphs used for visual analysis followed standard conventions, for example x- and y-axes labeled clearly and logically, phases clearly labeled (A, B, etc.) and delineated with vertical lines, data paths separated between phases, consistency of scales	1	1	0	1	0	0	0	0
13. The authors reported tests of statistical analysis, for example celeration line approach, two-standard deviation band method, C-statistic, or other	0	0	1	0	1	0	1	1
14. All criteria were met for the statistical analyses used	1	0	1	0	1	0	1	0
Total score	11	10	11	10	11	11	11	11

The study obtained a score of 1 if it fulfilled the questions stated

Hodgetts et al. 2011a, b). The targeted behaviors in these studies were mostly classroom tasks, inclusive of increasing attention levels, reducing 'off-task' behaviors, while reducing stereotyped behaviors and self-stimulatory behaviors.

Weighted vests interventions demonstrated improved behaviors in one study (Fertel-Daly et al. 2001), mixed results in two studies (Hodgetts et al. 2011a, b), and no benefit in one study (Collins and Dworkin 2011). Improved

behaviors reported in Fertel-Daly et al. (2001) included reductions in classroom distractions and repetitive and stereotyped behaviors. While Hodgetts et al. (2011a) did not find reductions in stereotypic behaviors, 'off-task' behaviors or inattention. Improvement in verbal stereotyped behaviors occurred in one participants.

In Fertel-Daly et al. (2001), a weighted vest was worn three times a week for 2-h duration and were removed 2 h,

Table 3 Summary of the study details

Studies	Design	Objectives	Participants	Number of participants	Age (years) (range; mean)	Gender (number) (male, female)	Outcome measures	Interventions ^a	Results
Escalona et al. (2001)	Randomized control trials	To investigate the improvements in behaviors of children with autism spectrum disorder following massage therapy	Autism spectrum disorder	20	3–6; 5.2	12, 8	Revised Conner's Teacher and Parent Scales Classroom and playground behavior observations Sleep diaries	Experimental group: massage therapy (tactile) Control group: reading	Effective result: exhibit less stereotypical behaviors, showed more on task and social behaviors during play observations at school and fewer sleep problems at home
Field et al. (1992)	Randomized control trials	To examine the independent effects of the massage component on the behaviors and physiology of children and adolescents who were hospitalized for depression or adjustment disorders	Depression and adjustment disorders (conduct disorders and oppositional disorders)	72	7–18; 13.0	40, 32	The state anxiety inventory for children The profile of mood states Behavior observation ratings and activity levels Physiological and biomedical measures Night-time sleep recordings to observe behavior patterns during sleep	Experimental group: massage (tactile) Control group: videotape viewing	Effective result: less depress and anxious with lower saliva cortisol level and increase in sleep
Field et al. (1997)	Randomized control trials	To examine the effect of touch therapy in attentiveness and responsiveness in autism spectrum disorder children	Autism spectrum disorder	22	3–5; 4.4	12, 10	Autism behavior checklist Early Social Communication Scales	Experimental group: touch therapy (tactile) Control group: selecting toys of different colors/forms/shapes	Effective result: improved in behaviors (touch aversion and off tasks behaviors), shows less autistic behaviors, increase social and attentiveness in the classroom

Table 3 continued

Studies	Design	Objectives	Participants	Number of participants	Age (years) (range; mean)	Gender (number) (male, female)	Outcome measures	Interventions ^a	Results
Khilnani et al. (2003)	Randomized control trials	To investigate the effect of massage therapy on mood and behaviors of attention deficit hyperactive disorders students	Attention deficit hyperactive disorders	30	7–18; 13.0	24, 6	Conner's Teacher Rating Scale Saliva samples to indicate stress rates Mood state pictorial self-report Modified children pain/fear thermometer rating scale	Experimental group: massage therapy (tactile) Control group: waitlist control group (no treatment received)	Effective result: improving short-term mood state and longer term classroom behaviors
Pravej et al. (2009)	Randomized control trials	To evaluate whether there are any therapeutic effects of Thai traditional massage on major behavioral and emotional disturbances in Thai autistic children	Autism spectrum disorder	60	3–10; 4.0	49, 11	Conners' Parent Rating Scales Conners' Teacher Rating Scales Sleeping diary	Experimental group: Thai traditional massage (tactile) Control group: behavioral therapy	Mixed result: improvement in conduct problem, hyperactivity, inattention-passivity, hyperactivity index and sleeping behavior from the Conner's Teacher Questionnaire and sleep diary Anxiety improvement was only shown in the Conner's Parent Questionnaire in the intervention group
Silva et al. (2009)	Randomized control trials	To evaluate the effect of a 5-month intervention directed toward improving sensory impairment, digestion, and sleep in 46 children with autism	Autism spectrum disorder	46	3–6; 2.6	37, 9	Pervasive developmental disorders Behavior inventory Autism behavior checklist Sense and self-regulation checklist Videotape segments	Experimental group: Qigong massage (tactile) Control group: waitlist control group (no treatment received)	Effective results: improvement of social and language skills with a reduction of autistic behaviors compared to the control group based on the teacher's evaluation

Table 3 continued

Studies	Design	Objectives	Participants	Number of participants	Age (years) (range; mean)	Gender (number) (male, female)	Outcome measures	Interventions ^a	Results
Collins and Dworkin (2011)	Single-subject design	To investigate the effectiveness of a weighted vest on attention to task for second-grade general education students with difficulty attending	ADHD and children with difficulty in attention with the criteria of: Staying in own seat, difficulty in attention, need frequent reminder, frequently ask irrelevant questions	11	7.5–10.3; not mentioned	8, 3	Videotaped segments Non-standardized follow up survey for teachers	Weighted vest (proprioception)	No benefit: no significant differences were found. Weighted vest were not effective in reducing off tasks behaviors in children
Hodgetts et al. (2011a)	Single-Subject Design	To investigate the effects of weighted vests on classroom behavior for children with autism	Autism spectrum disorder with cognitive impairments	10	3–10; 5.9	8, 2	Conners' Global Index-Teacher, Videotape segments	Weighted vests (proprioceptive)	Mixed result: weighted vest did not decrease stereotypic behaviors in all participants, but verbal stereotyped behaviors decreased in one participant
Bagatell et al. (2010)	Single-subject design	To assess the effectiveness of therapy ball chairs on classroom participation in children with autism spectrum disorders	Autism spectrum disorder	6	6–7; not mentioned	6, 0	Videotape segments	Therapy ball (vestibular)	Effective result: therapy ball were seen effective in children who demonstrate extreme vestibular-proprioceptive seeking behaviors
Davis et al. (2011)	Single-subject design	To analyze the effect of brushing protocol on autism child with stereotypical behaviors	Autism spectrum disorder	1	4; 4	1, 0	Videotape segments	Brushing (tactile)	No benefit: there were no effect on level of stereotypy after brushing protocol were implemented
Fertel-Daly et al. (2001)	Single-subject design	To examine the effectiveness of weighted vest in increasing attention and reducing self-stimulatory behaviors	Pervasive developmental disorders	5	2–4; 2.2	3, 2	Videotape segments	Weighted vests (proprioceptive)	Effective result: weighted vest increase attention on tasks, decreased number of distractions and decrease self-stimulating behaviors

Table 3 continued

Studies	Design	Objectives	Participants	Number of participants	Age (years) (range; mean)	Gender (number) (male, female)	Outcome measures	Interventions ^a	Results
Hodgetts et al. (2011b)	Single-subject design	To investigate the effects of wearing a weighted vest on stereotyped behaviors and heart rate of children with autism in the classroom	Autism spectrum disorder	6	4–10; 6.6	5, 1	Polar vantage XL heart rate monitor Videotaped segments	Weighted vests (proprioceptive)	Mixed result: weighted vest did not improve sitting in all participants. However, it was reported to show improvements in classroom behaviors at least some of the time
Jenkins and Reed (2013)	Single-subject design	To evaluate the effect of therapeutic horseback riding on the behaviors of children with autism spectrum disorders	Autism spectrum disorder	7	6–14; 9.5	6, 1	The child behavior checklist Bruininks-Oseretsky test of motor proficiency	Therapeutic horseback riding (vestibular)	No benefit: there was no systematic change in the behaviors of children after therapeutic horseback riding. Changes are only seen in posture in three of four participants
Umeda and Dritz (2011)	Single-Subject Design	To investigate the effect of therapy cushions on the in-seat and on-task behaviors in children with autism spectrum disorders	Autism spectrum disorder	2	5–6, 5.6	2, 0	Videotape segments	Therapy cushions (vestibular)	No benefit: no improvement were seen in the in-task or on-task behaviors after therapy cushions were used

^a Experimental and control group intervention was listed for the randomized controlled trials

Table 4 Targeted behavioral problems in all studies

Interventions	Studies	Targeted behavioral problems
Tactile-based	Escalona et al. (2001)	Hyperactivity, restless-impulsive, stereotypical and sleep problems (fussing, restlessness, crying, self-stimulating, number of time children left the bed)
	Field et al. (1992)	Emotional disturbances including depression, anxiety (fidgeting), muscle tensions, increase cortisol level and sleep disturbances
	Field et al. (1997)	Inattentiveness (off-task behaviors), touch aversion, withdrawal, orienting to irrelevant sounds and stereotypical behaviors
	Khilnani et al. (2003)	Behavioral (restlessness, inattention and impulses;) emotional (depress, mood changes) and physiological
	Piravej et al. (2009)	Stereotypical behaviors, hyperactivity, inattention-passivity, anxiety, conduct problems and sleeping behaviors
	Silva et al. (2009)	Autistic behaviors, sensory and self-regulatory disturbances, digestion and sleep
	Davis et al. (2011)	Stereotyped behavior; hand flapping, finger flicking and body rocking
Proprioceptive-based	Collins and Dworkin (2011)	Off tasks behaviors in the classroom; difficulties staying in own seat, difficulties staying in own seat, difficulty keeping eyes on teachers, boards or own work, needs frequent reminder to work on tasks and ask irrelevant questions or off topic questions
	Hodgetts et al. (2011a)	Stereotyped behaviors; Flicking objects, hand and finger mannerisms, echolalia, spinning objects, rocking and hand flapping
	Hodgetts et al. (2011b)	Classroom off-tasks behaviors; looking away from the activity or not participating in the intended functional manipulation of materials related to activity, response appropriately to external prompts, difficulty sitting
	Fertel-Daly et al. (2001)	Attention to task (distractions of turning eyes or head away from tasks) and self-stimulatory behaviors (repetitive, stereotyped mannerisms such as rocking, spinning objects, twirling, arm flapping, gazing, tapping, hand biting, flickering ears, crossing eyes, rolling eyes, squinting or repetitive and monotonous vocalization)
Vestibular-based	Bagatell et al. (2010)	In-seat behaviors (participant's buttocks in contact with the ball, the ball in contact with the floor) and engagement (oriented towards appropriate classroom activity or teacher and either interacting with materials, responding to speaker or looking at the speaker)
	Jenkins and Reed (2013)	Problem behaviors; aggression, pica, stereotypical (hand flapping, body rocking, finger posturing, non-contextual vocalizations), screaming or other inappropriate vocalization and property destruction (tearing, throwing, ripping)
	Umeda and Deitz (2011)	Out-of-seat behaviors; participants buttocks left contact with the seat and any chairs left contact with the floor Off-tasks-behavior; loss of visual orientation to activity or teacher, inappropriate manipulation of activity-related materials and failure to respond or provide verbal responses

before wearing it again during the intervention phase over the period of 6 weeks. In Hodgetts et al. (2011a, b), weighted vest was put on for a 20-min duration each day during the intervention phase for 9 weeks period (Hodgetts et al. 2011a) and 5 weeks period (Hodgetts et al. 2011b). In (Collins and Dworkin 2011), weighted vests were worn every day during school day for 3–6 weeks duration. Specific hours of weighted vests wearing were not stated in the study.

Vestibular-Based Intervention

Three single-case studies investigated the use of vestibular stimulation. One study examined the use of a therapy ball to children's in-seat behaviors and engagement in

the classroom (Bagatell et al. 2010). Another study implemented therapy cushions targeting out-of-seat behaviors and 'off-task' behaviors (Umeda and Deitz 2011). The third study trialed the use of therapeutic horseback riding to reduce behavioral problems such as aggression, stereotypical and other inappropriate behaviors (Jenkins and Reed 2013). Only the study using the therapy ball produced positive behavioral results including increased 'in-seat' behaviors and engagement in classroom activities (Bagatell et al. 2010). Therapy ball interventions may therefore provide an appropriate level of vestibular stimulation to counter extreme vestibular-proprioceptive seeking behaviors in children, enabling greater classroom participation.

Bagatell et al. (2010) applied therapy balls during circle time each day of school for a total of 16 min per day over a period of 19 days. In Umeda and Deitz (2011), therapy

cushions were applied only during Math time which lasted for 10–15 min per day during intervention phase for a total of 13.5 weeks of study period. In Jenkins and Reed (2013), therapeutic horseback riding was allowed for participants once a week for 60 min therapy session over a 9 week period. The time session for this study was the longest, compared to Bagatell et al. (2010) and Umeda and Deitz (2011).

Discussion

Appropriate intervention to address behavioral problems in children is important to allow for appropriate learning (Devlin et al. 2011). Applying appropriate intervention not only helps children to identify targeted behaviors but also shortens the time spent on unnecessary stimulations. For these reasons, finding the most effective intervention to reduce behavioral problems in children is essential.

This systematic review examined clinical evidence on the use of sensory-based stimulations in children with behavioral problems. Fourteen studies, six RCTs and eight single case studies, were included in this review. The studies represented three main types of SBI including tactile, proprioceptive and vestibular stimulations with different methodological approaches.

Among the three types of interventions used, tactile stimulation was most commonly reported to address behavioral problems in children. Six out of seven studies using tactile stimulation reported effective results with all level 1 hierarchy of evidence. Massage therapy was the most common tactile-based intervention with consistent positive results. This supports the use of tactile stimulation in clinical practice. Recommendations for massage therapy include mid-afternoon application, between 15 and 30 min, two to three times per week for one to 3 months duration. Piravej et al. (2009) applied the massage sessions up to 1 h per session, but this was shown to have only a somewhat positive effect. The child's comfort and anxiety levels as well as level of cooperation and distractions also need consideration (Case-Smith and Arbesman 2008; Piravej et al. 2009). These may be achieved through the therapy room set-up, and building on a good therapist-child rapport prior to the intervention.

Caution needs to be considered when applying tactile stimulations. Responses to tactile sensory can either be defensiveness or under responsiveness contributed by inefficient processing of sensory stimuli (Bundy et al. 2002). While the right amount of tactile stimulation may rectify the perception of sensory stimuli and reduce the effect of defensiveness or under responsiveness on behaviors in children (Ayres 1979, 1991) and as evidenced by this systematic review (Piravej et al. 2009), longer

duration of stimuli may not be beneficial. Therapists should therefore assess the level of tactile response of the child and determine if he or she is seeking or avoiding the stimulation in order to provide the most appropriate level and type of tactile stimulation.

Applying proprioceptive stimulation has been reported to benefit primarily in-classroom behaviors, difficulties staying on seat, off-task behaviors and inattention issues in the classroom (Fertel-Daly et al. 2001; Hodgetts et al. 2011b). However, only one study out of four in this systematic review showed a reduction in these behaviors (Fertel-Daly et al. 2001) while one study showed improvement in one child (Hodgetts et al. 2011b). Recommendations for weighted vest therapy include three times a week for 2-h duration and removed 2 h before wearing again (Fertel-Daly et al. 2001). Twenty minute duration per day was not as effective (Hodgetts et al. 2011a, b). The longer and more consistent duration of wear through the day appears more effective for children with behavioral problems. However, the evidence to support proprioceptive stimulations in reducing behavioral problems remains weak. This finding is consistent with a previous systematic review conducted by Stephenson and Carter (2009) that applying proprioceptive input using weighted vest had no benefit for children with ASD and other clinical conditions who had inattentiveness, hyperactivity, stereotypic behaviors, and clumsiness. It was postulated by Ayres (1991) that proprioceptive stimulation was usually accompanied by problems of tactile system within the body rather than proprioceptive problems alone. Applying proprioceptive stimulations alone, as an intervention to reduce behavior problems in children, may be indirect and not address all the sensory needs of the child.

The clinical evidence to support vestibular stimulation in reducing behavioral problems in children is also limited. In this systematic review, only Bagatell et al. (2010) showed effective results using therapy balls for 16 min of classroom sessions for 19 days for children with behavioral problems. While the therapy ball intervention is promising, there is limited evidence to support and to draw definitive conclusions about this type of intervention.

Despite the limited clinical evidence, vestibular stimulation has raised considerable discussions in the literature. Kern et al. (2007) revealed that symptoms of autism such as spinning or having difficulty navigating steps on an uneven ground are related to registration and modulation of vestibular stimulations. Another study conducted by Molloy et al. (2003) suggested that stereotype behaviors like sways or body rocking that occur in children with autism are related very closely to vestibular problems. Ottenbacher (1993) suggested vestibular has a positive effect in children's level of alertness in classroom and thus could reduce behaviors such as crying, engaging in self-injury and

stereotyped pattern of behaviors. White-Traut et al. (1993) reported an increased alertness and reduced behavioral problems in infants who received vestibular stimulation through rocking. Gregg et al. (1976) reported a reduction of uneasiness behavior and crying following vestibular stimulations and an improvement in visual alertness and tracking among newborn baby.

Inattention problems such as difficulties staying calm and sitting down for class activities or stereotyped behaviors of rocking may therefore be related to registration and modulation of vestibular stimulations that interfere with children's ability to attend for learning (Case-Smith and O'Brien 2010; Kern et al. 2007). These problems are contributed to by deficiencies in the central nervous system, which attempts to organize the sensory demands from the environment (Ayres and Robbins 2005). A study conducted to a group of rhesus monkeys indicated that the postrotary nystagmus as a measure of their vestibular function was related to individual differences in temperament (Schneider and Suomi 1992). This further supports, though indirectly, that the function of vestibular system is closely related to the one's attention control and behavior such as temperament. Therefore, by providing the appropriate vestibular stimulation necessary to stimulate the vestibular system, vestibular stimulation has a calming effect on children that helps increase their alertness and reduce behavioral problems (Dunn 1996; Guess et al. 1999). Vestibular stimulation has been advocated for treating these children to enhance school learning such as reading and handwriting, and appropriate social behavioral such as adequate attention during social interaction (Chaikin and Downing-Baum 1997; Goldstand et al. 2005; Kawar 2002). Therefore, despite limited clinical evidence found in the selected studies, appropriate vestibular stimulation may help children to organize sensory demand of the environment and so to function with less maladaptive behaviors. Further research is required to investigate the use of this therapy in children with behavioral problems.

While some studies (for example, Ashburner et al. 2008; Bumin and Kayihan 2001; Candler 2003; Case-Smith and Bryan 1999) have demonstrated the effectiveness of SBI in treating children's sensory processing problems, the mechanism on how the SBI work is still not clear. The concept of neuroplasticity, the ability of the nervous system to change according to the stimulation provided by the SBI has been postulated (Case-Smith et al. 2015). Providing SBI with an appropriate modulation and integration may retrain neurological pathways modifying children's behavior (Baraneck 2002; Lane et al. 2010; Schaaf and Miller 2005). However, the exact nature of the nervous system impairment and the influence given by the sensory stimulations both warrant further investigation (Iarocci and McDonald 2006).

This study reviewed the evidence of SBI with either tactile, proprioceptive, or vestibular stimulations. The evidence gathered did not substantially support the use of SBI in general. Although this review sheds lights on the effects of different types of sensory stimulations on enhancing one's behaviors, questions still exist on how stimulations are selected for children with behavioral problems. Perhaps a similar way as adopted by Mason and Iwata (1990) in using functional analysis to map the specific treatment to be offered could be adopted. Further studies are needed to develop a comprehensive method to assess the nature of behavioral problems and to select the most appropriate sensory stimulation for children in need. Another possible reason could be due to the lack of measurement of functional outcome. Most studies included in this review used outcome measures on behaviors but not the functional outcomes of behavioral problems. Applying sensory stimulations without regard to functions of behaviors might create a wrong concept for the individuals that they could escape from demanding functional tasks while receiving the sensory intervention. We also postulated that the lack of substantial support on the use of SBI as reviewed in this study could be related to the offer of singular tactile, proprioceptive or vestibular stimulations alone. As postulated by Ayres (1991), dysfunction in sensory processing is multilayered without reliance on a single sensory system. Applying singular tactile, proprioceptive or vestibular stimulations alone may not fulfill all the complicated sensory needs of the children. All the SBI reviewed here used only individual sensory stimulation. A comprehensive multilayered SIT would be more effective if sensory processing is a complicated dysfunction. As mentioned earlier, SIT involves the use of a variety of sensory stimulations. Therapist using SIT will need to follow the ten fidelity measures as stated by Parham et al. (2007). This includes the need to (1) provide sensory opportunities; (2) provide just-right challenges; (3) collaborate on activity choice, (4) guide self-organization; (5) support optimal arousal; (6) create play context; (7) maximize a child's success; (8) ensure physical safety; (9) arrange room to engage child; and (10) foster a therapeutic alliance. Further studies examining the effectiveness and application of SIT would be necessary.

Conclusions

This systematic review has examined the evidence for SBI in children with behavioral problems that affect their school, daily livings and social participation. Tactile stimulation shows the best clinical evidence for reduction of behavioral problems in children including improving inattention and participation in the classroom and

increasing the ability to socialize, compared to proprioceptive and vestibular stimulations. Numerous previous studies reported the benefit of using vestibular stimulation through enhancing one's attention and temperament, thus reducing children's behavioral problems. However, if the dysfunction in sensory processing is multifaceted, a comprehensive and tailored-made SIT would be needed to address the specific sensory processing problems of the child. More research is needed to fill in gaps in the literature concerning the reduction of behavioral problems in children and enhance their school, daily livings and social participation.

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