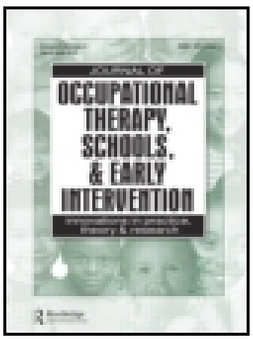

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# A systematic review of sound-based intervention programs to improve participation in education for children with sensory processing and integration challenges

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**ABSTRACT**

This systematic review evaluates current evidence for using sound-based interventions (SBIs) to improve educational participation for children with challenges in sensory processing and integration. Databases searched included CINAHL, MEDLINE Complete, PsychINFO, ERIC, Web of Science, and Cochrane. No studies explicitly measured participation-level outcomes in education. Ten studies provided limited evidence supporting the use of SBIs based on preliminary positive effects on occupations, client factors, and performance skills related to participation in education. Stronger experimental designs are needed measuring educational participation. Therapists should use caution using SBIs for this population and outcome until further research clearly substantiates or refutes this intervention.

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Sound based intervention; sensory processing; children; auditory perception; sound; education; participation

The sensory-rich nature of the everyday school environment can threaten the learning and full educational participation of children with challenges in sensory processing and integration. Children with challenges in sensory processing and integration present with difficulties in "detecting, regulating, interpreting, and responding to sensory input which impairs [one's] daily routines or roles" (Miller, Anzalone, Lane, Cermak, & Osten, 2007, p.136). Evidence suggests children and adolescents who have challenges in sensory processing and integration have lower participation in educational activities and decreased academic performance (Ashburner, Ziviani, & Rodger, 2008; Bar-Shalita, Vatine, & Parush, 2008; Koenig & Rudney, 2010). A multitude of educational activities such as completing classroom work, playing during physical education and recess, or eating lunch in the cafeteria requires discrete processing and integration of sensory information putting students who have difficulty with this process at risk for decreased participation in educational activities. Current evidence indicates the prevalence of children without identified diagnoses experiencing challenges in processing and integrating sensory information ranges from 15.8–16.5% (Ben-Sasson, Carter, & Briggs-Gowan, 2009; Fernandez-Andres, Pasto-Cerezuela, Sanz-Cervera, & Tarraga-Minguez, 2015) and from 40% to 88% in children with diagnoses (Cheung & Siu, 2009; Fernandez-Andres et al., 2015). Addressing the unique needs of children with challenges in sensory processing and

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integration in the school environment is critical to ensure that all children have access to their legally mandated educational program.

School-based occupational therapists are distinctly positioned to provide services and interventions to support children with challenges in sensory processing and integration to maximize their educational participation. Occupational therapists have not only the theoretical education and clinical training in sensory processing, but also the professional purpose of supporting children's participation in everyday occupations. Participation in education is one of the primary childhood occupations, and is defined as engagement in activities needed for learning and participating in the educational environment (American Occupational Therapy Association [AOTA], 2014). The Individuals with Disabilities Education Improvement Act (IDEA) mandates that school-based occupational therapists apply scientifically based skills and knowledge to improve services and outcomes for children with disabilities (IDEA, 2004, section 662.2). For evidence-based services, school-based occupational therapists should apply interventions not only supported by clinical expertise and client preferences, but also by research (Sackett, Rosenberg, Muir Gray, Haynes, & Richardson, 1996).

Sound-based intervention (SBI) programs are an approach increasingly used by school-based occupational therapists to support children with challenges in sensory processing and integration with the intent to improve children's participation in education (Bazyk, Cimino, Hayes, Goodman, & Farrell, 2010). SBI programs involve listening to electronically modified music, nature sounds, or a voice using specialized equipment such as bone conduction headphones and an amplifier. A variety of SBI programs exist including: The Listening Program (TLP) (Advanced Brain Technologies, 2017), Therapeutic Listening (Vital Links, 2017), and Integrated Listening Systems (iLs; Integrated Listening Systems, 2017).

Despite the popularity of SBI programs in supporting children with challenges in sensory processing and integration, evidence of the intervention in improving a child's participation in education is lacking. Previous SBI systematic reviews and a meta-analysis reported mixed results, and the implications of studied outcomes on school participation remain unclear. Sinha, Silove, Hayen, and Williams (2011) as well as Sinha, Silove, Wheeler, and Williams (2006) systematically reviewed randomized controlled trials (RCTs) of studies using Auditory Integration Training (AIT) and the Tomatis Method on children and adults with ASD. Both reviews reported no evidence for improvement on outcomes pertaining to core and associated features of ASD. In contrast, Gilmor (1999) conducted a meta-analysis of five studies using the Tomatis Method for children with learning and communication disorders and reported positive effect sizes in linguistic, psychomotor, personal and social adjustment, cognition, and auditory domains using standardized measures of aptitude, achievement, and adjustment. Parental reports of improvement in children's learning, communication, and general adjustment supported the positive qualitative findings (Gilmor, 1999). More recently, Wink, McKeown, and Casey's (2017) qualitative study reported parents of children with sensory processing difficulties perceived reduced levels of their child's anxiety and distress after using Therapeutic Listening that related to improvements in family life and participation in social and daily activities. Vargas and Lucker (2016) performed a quantitative summary of nine studies using The Listening Program (TLP); however, included studies were

exploratory pilot studies, not yet published in peer-reviewed journals, with a wide variety of age ranges and outcomes examined.

A systematic review examining the use of SBI programs for improving participation in education in children with challenges in sensory processing and integration is needed to provide updated evidence to inform evidence-based practices for supporting participation in education. The purpose of this systematic review is to establish the current evidence in using SBIs to support children with difficulties in sensory processing and integration and their participation in education, and provide guidance for occupational therapists' clinical decision making. This systematic review examines the following research question: What is the evidence for using sound-based intervention programs to improve participation in education for children with challenges in sensory processing and integration?

## Method

A research team of two occupational therapists with robust experience in school-based practice, one occupational therapy researcher, and one university health science librarian completed this systematic review. The research team reviewed 34 full-text articles to determine evidence level and provide practice guidelines via the Preferred Reporting Items of Systematic Review and Meta-Analysis Protocol (PRISMA-P; Shamseer et al., 2015).

### *Search strategy*

The first author and an experienced health science librarian developed a comprehensive list of search terms which are available upon request. The researchers conducted an extensive database search utilizing the following databases: CINAHL, MEDLINE Complete, PsychINFO, ERIC, Web of Science, and Cochrane on October 14, 2015, and secondary search on June 7, 2017. Table 1 includes the ERIC search terms.

### *Inclusion and exclusion criteria*

The inclusion criteria for studies in this review were: peer-reviewed and published between 2000–2017, published in English, examined the use of a sound-based intervention, involved children aged from 2 to 19 with challenges processing and integrating sensory information explicitly stated within the article as determined by formal assessment including in some cases parent report, and examined outcomes related to participation in education. Participation in education was defined as an engagement in activities needed for learning and participating in the educational environment (AOTA, 2014). Due to the limited number of published experimental studies, evidence hierarchy Levels III and IV

**Table 1.** ERIC search string.

| | |
|---|---|
| Population | Disabilities, learning disabilities, learning problems, autism, pervasive developmental disorders, developmental delays, developmental disabilities, sensory processing, preschool children, adolescents |
| Intervention | Auditory stimuli, auditory training, acoustics, sensory aids, sensory integration, sensory training, auditory perception, occupational therapy, music, music therapy |
| Outcome | Skills, skill development, class activities, listening skills, academic ability, student behavior, learner engagement, student participation, participation, psychomotor skills, handwriting, writing skills, communication skills, interpersonal competence, attention, cognitive ability, thinking skills |

(Sackett et al., 1996) were included in the review. This study's exclusion criteria included: evidence hierarchy Level V (Sackett et al., 1996), qualitative studies, dissertations, theses, abstracts, and oral presentations.

### Extraction procedures

The initial results from all six database searches yielded 8,540 articles. An additional 21 articles were identified through hand searches and serendipitous findings. After removal of duplicates, the first author reviewed 7,364 titles and abstracts per the inclusion and exclusion criteria, leaving 34 articles for full-text review. The first two authors examined each article to determine if outcomes studied related to occupations, client factors, or performance skills relevant to participation in education. When disagreement occurred, the third author reviewed the full-text article and made the final decision on inclusion and through this process; the research team identified the final 10 articles included in the data analysis (Figure 1). The outcomes identified in the studies pertaining to participation in education were: attention, following directions, completing a task, person engagement, fine motor skills, visual motor skills, communication, social skills, sensory processing, and sensory modulation.

### Data analysis

The PRISMA-P (Shamseer et al., 2015) 17-item checklist for systematic reviews guided the review process, an Evidence Table Worksheet (Padilla, 2013) assisted with organization of the data, the Quality Index (Downs & Black, 1998) was used to assess the risk of bias; and a five-level grading evidence strength system adapted from the United States Preventive Services Task Force (USPSTF, 2016) provided a rating scale for the strength of evidence. The evidence table worksheet included participant demographics, levels of evidence, interventions, outcomes, outcome measures, and results summary (Padilla, 2013). The Quality Index (Downs & Black, 1998), a 27-item checklist, provided a score profile and total score based on a study's risk of bias in reporting, measurement of the intervention and outcome, participant selection, external validity, and power of the study to enable comparisons among reviewed studies. To determine whether a power calculation or sample size calculation was provided in the study, scoring on item 27 was modified to score either "0" or "1". The total score is grouped into four quality levels: excellent (24–28 points), good (19–23 points), fair (14–18 points), and poor (13 or less points). The Quality Index has evidence of high test-retest reliability ($r$ = .88), high criterion validity correlates ($r$ = 0.90), and adequate inter-rater reliability ($r$ = 0.75; Downs & Black, 1998). All authors assessed each article and any discrepancies in the rating were resolved by discussion until agreement occurred about the item in question.

During data analysis, the studies were grouped by sound-based intervention program and outcomes relevant to participation in education. A qualitative data synthesis was performed using the strength of the evidence five-level grading system adapted from the USPSTF (2016). A designation of strong evidence was based on consistent results from well-conducted studies and usually at least two RCTs. A designation of moderate evidence was made based on results from one RCT, or two or more studies with lower levels of evidence. The designation of limited evidence was made based on results from a few

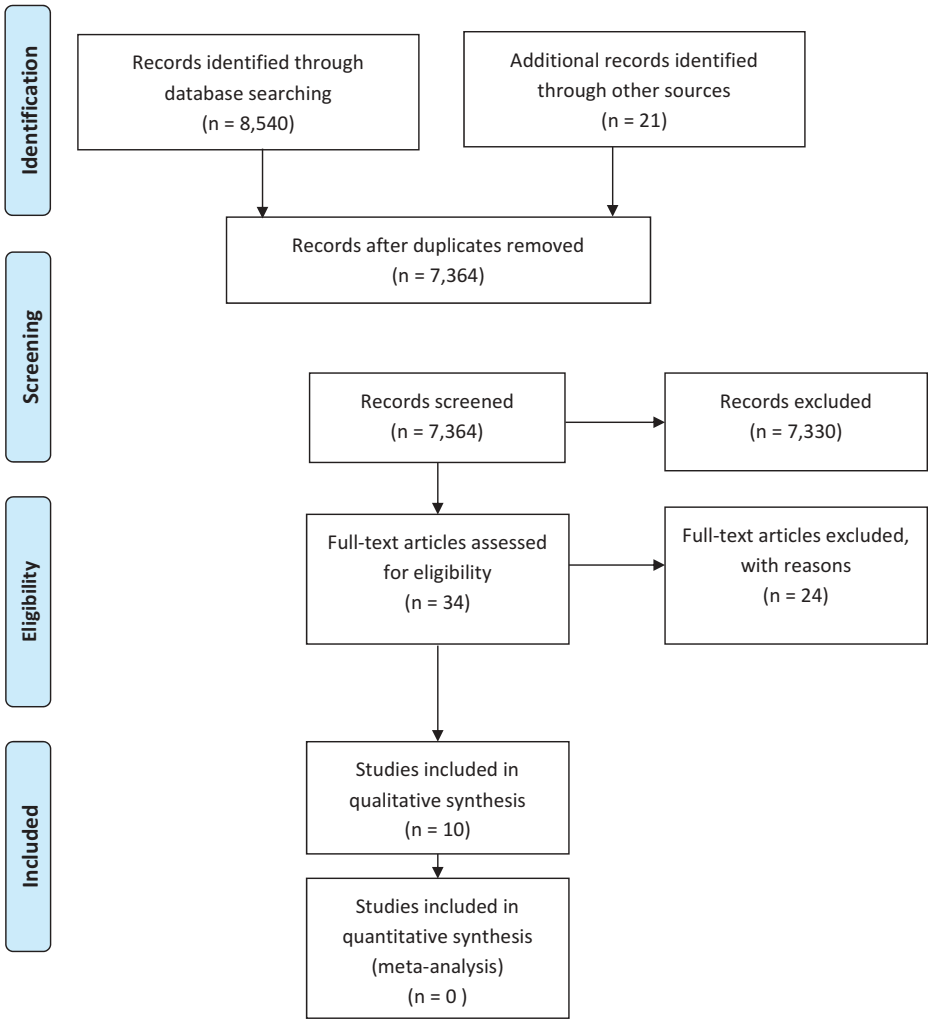


**Figure 1.** Preferred reporting items for systematic reviews and meta-analyses flow diagram of published literature search.

*Note*. Prisma Flow Diagram is from "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement", by D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, & The PRISMA Group, 2009, *Annals of Internal Medicine, 151*(4), p. 264–269. doi: 10.7326/0003–4819-151–4-200908180–00135

studies, flaws in the available studies, or some inconsistency in the findings across individual studies. A designation of mixed evidence was based on inconsistent results from the study findings across studies within a category. Insufficient evidence was designated when the number and quality of studies were too limited to make any clear classification.

## Results

Ten studies measured outcomes of relevance to participation in education as result of a sound-based intervention for children with challenges processing and integrating sensory information. No single study within our search explicitly measured participation-level educational outcomes such as the child's level of participation in school-related activities such as in classroom settings, on playgrounds, or during lunch mealtimes and other self-care activities. The identified articles encompassed four SBI programs: AIT (AIT Institute, 2017), iLs (Integrated Listening Systems, 2017), TLP (Advanced Brain Technologies, 2017), and Therapeutic Listening (Vital Links, 2017). A total of 185 children utilized a SBI program: 138 utilized AIT, 25 utilized Therapeutic Listening, 15 utilized TLP, and 7 children utilized iLs. The children ranged from 3 to 19 years of age: AIT listeners were ages 3–17, Therapeutic Listening listeners were ages 3–11, TLP listeners were ages 5–19, and iLs listeners were ages 4–18.

All children in the studies experienced reported challenges in processing and interpreting sensory information, with most children reported to have general sensory processing difficulties ($n$ = 102), sensory modulation difficulties ($n$ = 54), and combinations of sensory processing and sensory modulation difficulties ($n$ = 53; Table 2). One study reported participants' scores on the sensory/cognitive awareness section of the Autism Treatment Evaluation Checklist (ATEC; Vadivel & Missal, 2014). Seven studies reported specific types of sensory modulation difficulties (Al-Ayadhi, Al-Drees, & Al-Arfaj, 2013; Brockett, Lawton-Shirley, & Kimball, 2014; Francis, 2011; Gee, Thompson, Pierce, Toupin, & Holst, 2015; Gee, Thompson, & St. John, 2014; Nwora & Gee, 2009; Schoen, Miller, &

**Table 2.** Participants' type of sensory processing and sensory modulation challenges.

| Type of SP and SM difficulties | Number ($n$) | Author/Study, number ($n$) |
|---|---|---|
| SP difficulties | $n$ = 102 | Al-Ayadhi et al., ($n$ = 72)<br>Bazyk et al., ($n$ = 15)<br>Brockett et al., ($n$ = 4)<br>Hall et al., ($n$ = 10)<br>Nwora et al., ($n$ = 1) |
| SM difficulties (general) | $n$ = 54 | Brockett et al., ($n$ = 54) |
| Auditory sensory over responsivity/sound sensitivity | $n$ = 68 | Al-Ayadhi et al., ($n$ = 41)<br>Brockett et al., ($n$ = 6)<br>Francis et al., ($n$ = 10)<br>Gee, Thompson, St. John ($n$ = 1)<br>Gee, Thompson, Pierce et al., ($n$ = 3)<br>Schoen et al., ($n$ = 7) |
| Sensory seeking | $n$ = 4 | Nwora et al., ($n$ = 1)<br>Schoen et al, ($n$ = 3) |
| Oral sensory sensitivity | $n$ = 1 | Nwora et al., ($n$ = 1) |
| Tactile over-responsivity | $n$ = 17 | Francis et al., ($n$ = 1)<br>Schoen et al., ($n$ = 7) |
| Sensory under responsivity | $n$ = 2 | Nwora et al., ($n$ = 1)<br>Schoen et al., ($n$ = 1) |
| Sound sensitivity and SP | $n$ = 41 | Al-Ayadhi et al., ($n$ = 41) |
| SM and SP | $n$ = 4 | Brockett et al., ($n$ = 4) |
| SP, sensory seeking, oral sensory sensitivity, sensory sensitivity, and under registration | $n$ = 1 | Nwora et al., ($n$ = 1) |
| Tactile and auditory over-responsivity, sensory seeking, sensory under-responsivity | $n$ = 7 | Schoen et al., ($n$ = 7) |

*Note.* SM = sensory modulation. SP = sensory processing.

Sullivan, 2015) with the most common type experienced by participants involving sensory overresponsivity (SOR) or auditory sensitivity (Al-Ayadhi et al., 2013; Brockett et al., 2014; Francis, 2011; Gee et al., 2015, 2014; Schoen et al., 2015). Other categories of participants' sensory modulation challenges described in the studies included tactile sensitivity, oral SOR, sensory underresponsivity (SUR), and sensory seeking (SS; Table 2). Participants across the 10 studies also had varying diagnoses such as autism spectrum disorder (ASD), attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD), and developmental delays.

The 10 studies scored an average Quality Index score of 18 (fair), with a range from 13 to 21 points (poor to good quality). Three studies received a good quality rating (Bazyk et al., 2010; Francis, 2011; Hall & Case-Smith, 2007), six studies obtained a fair rating (Al-Ayadhi et al., 2013; Brockett et al., 2014; Gee et al., 2015, 2014; Nwora & Gee, 2009; Schoen et al., 2015), and one study received a poor rating (Vadivel & Missal, 2014). The studies consisted of one Level II pretest/posttest quasi-experimental design with a control group (Vadivel & Missal, 2014), two Level III one group pretest/posttest design (Al-Ayadhi et al., 2013; Bazyk et al., 2010), and seven Level IV single case studies (Brockett et al., 2014; Francis, 2011; Gee et al., 2015, 2014; Hall & Case-Smith, 2007; Nwora & Gee, 2009; Schoen et al., 2015).

Improvements in occupation-based outcomes reported across the studies with $p < 0.01$ included the following: completes spelling work in a timely manner, completes homework in a timely manner, completes writing assignments without emotional incident, and completes morning routines without incident. Improvements in performance skills and client factors with the potential to support a child's participation in education as result of the SBI program with $p < 0.05$ included fine motor skills, visual motor skills, communication and social skills, following directions ($p < 0.001$), and sensory modulation ($p < 0.01$). Auditory SOR, auditory filtering, and visual/auditory sensitivity were combined under sensory modulation.

### *Auditory integration training (AIT)*

According to AIT developers, Berard AIT retrains an individual's disorganized auditory system to perform more efficiently (AIT Institute, 2017). Since different frequencies of sound relate to different body functions, by improving auditory processing, many areas of function can be addressed (AIT Institute, 2017). AIT consists of listening to modulated music using a specially designed AIT device and high-quality headphones for a total of 10 hr over 10 to 12 consecutive days guided by a trained AIT practitioner (AIT Institute, 2017).

Three studies examined the use of AIT on improving children's communication, social skills, and sensory modulation (Al-Ayadhi et al., 2013; Brockett et al., 2014; Vadivel & Missal, 2014). Scores on the Quality Index ranged from 13 to 18, demonstrating a poor to fair quality rating (Table 3). Although positive results were reported by all three studies using AIT, limitations with internal and external validity of the studies limit generalizability of the findings and overall study rigor. The limitations for all three studies include use of convenience sampling, heterogeneous samples (severity of ASD levels, participant's mixed diagnoses), and lack of standardized outcome measures. In one study, there was potential bias in the assessment of the outcomes using a parent-rated questionnaire: the

**Table 3.** SBIs and outcomes related to participation in education.

| Author/Year | Level of evidence/study design/ participants/inclusion criteria | SBI & other services | Outcomes related to participation in education | Results | Downs & Black Quality Index |
|---|---|---|---|---|---|
| Al-Ayadhi et al.,(2013) | Level III<br>Pretest/PostTest<br>*n* = 72, 97% Male, 3% Female;<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (sensory sensitivity/ insensitivity)<br>• Age: 3–17 yrs.<br>No control group | AIT 2×/day, 30 min. each, for 2 weeks Other services not reported | Social awareness, Social cognition, Social communication, Social motivation, (SRS) communication, Sociability, Sensory/Cognition (ATEC) *(Performance Skills)* | Statistically significant changes in social awareness, social cognition, and social communication w/*p* value < 0.05<br>Statistically significant changes in communication and sociability w/*p* value < 0.05 | 18 Fair |
| Brockett et al., (2014) | Level IV<br>Retrospective Chart Review<br>*n* = 54, 83% Male, 17% Female;<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (visual/auditory sensitivity, auditory filtering, under-responsivity, movement sensitivity, tactile sensitivity)<br>• Age: 3–10 yrs.<br>No control group | AIT 2×/day, 30 min. each, for 10 days Other services not reported | Sensory Modulation (SSP) *(Client Factors)* | All individual factors of the SSP showed significant changes at 1, 3, 6 mos. post AIT w/*p* value < 0.01 in: Tactile Sensitivity Taste/Smell Sensitivity Movement Sensitivity Auditory filtering<br>Low energy/weak Visual/auditory sensitivity Under-responsivity w/p value < 0.03 | 18 Fair |
| Vadivel and Missal (2014) | Level II<br>Pretest/Posttest Quasi-Experimental Design<br>*n* = 12, 66%Male, 34%Female<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (auditory sensitivity)<br>• Age group 3.5 – 6 yrs.<br>Control Group:<br>OT, SI, & Spec. Ed. | AIT 2×/day, 30 min. each for 10 days (SBI only) | Speech/language/ communication, Sociability, Sensory/ Cognition (ATEC) *(Performance Skills)* | Significant changes in pre/post test scores of the intervention group in ATEC components in speech/ language/communication, sociability, sensory/cognition, w/*p* = 0.005<br>Significant changes also noted in pre/ post test scores of the control group in ATEC components in speech/ language/communication, sociability, sensory/cognition w/*p* = < 0.10, < 0.005, < 0.05 respectively | 13 Poor |

| | | | | | |
|---|---|---|---|---|---|
| Bazyk et al. (2010) | Level III<br>Pre-Experimental Pretest/Posttest;<br>*n* = 15, 66%Male, 34%Female<br>Inclusion Criteria:<br>• SPD: Sensory Processing/ Sensory Modulation<br>• Age: 3–6 yrs.<br>No control group | TL 1–2×/day, 20–30 min. each, 5 days/wk. for6–20 weeks; + Typical therapy services | Fine Motor,(PDMS-2) Visual-motor skills,(VMI) Social skills(SSRS)Sensory processing(SP)*(Client Factors &Performance Skills)* | Significant changes noted from pretest to posttest scores with *p* value < 0.05in fine motor (PDMS-2 composite score)visual motor (VMI composite std. score)social skills (SSRS – Social skills std. score)No significant changes noted in the Sensory Profile subtests | 21 Good |
| Hall and Case-Smith (2007) | Level IV<br>Multiple Single Subject Series<br>*n* = 10 (12), 90%Male, 10%Female<br>Inclusion Criteria:<br>• SPD: Sensory Processing<br>• Age: 5–11 yrs.<br>No control group | TL2×/day, 20–30 min. each for8 weeks+Sensory Diet;Some w/OT | Visual-motor skills(VMI, ETCH)Sensory Processing (SP)*(Client Factors &Performance Skills)* | Significant changes from pretest to posttest scores noted in visual & motor scales of VMI, and lowercase, number, and total legibility scores of the ETCH,w/*p* value < 0.05Significant improvements noted in 9 of the 14 subtests of the Sensory Profile, w/*p* value <_ 0.05 in:Auditory processingTouch processingMultisensory processingOral sensory processingBody position & movementEmotional responsesModulation of visual input affecting emotional responsesEmotional/social responsesBehavioral outcomes | 21 Good |
| Francis (2011) | Level IV<br>Multiple Single Case Studies<br>*n* = 10 (12), 42%Male, 58%Female<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (difficulties tolerating or con-centrating on sounds)<br>• Age: 9–19 yrs.<br>No control group | TLP1×/day,15 min. each,5 days/wk. for16 weeksOther servicesnot reported | Person engagement(Video recording/analysis; Profound Education Curriculum Profile; Questionnaire) *(Performance Skills)* | Increased person and/or activity engagement in 6/10 students (video analysis)8/12 students had higher level of achievement compared to the previous year (s) as reported in Profound Education Curriculum profile | 19 Good |

(*Continued*)

**Table 3.** (Continued).

| Author/Year | Level of evidence/study design/ participants/inclusion criteria | SBI & other services | Outcomes related to participation in education | Results | Downs & Black Quality Index |
|---|---|---|---|---|---|
| Gee et al.,(2014) | Level IV<br>ABA Single Subject Case-controlled<br>*n* = 1, 100% Female<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (auditory sensory overresponsivity)<br>• Age = 7 yrs.<br>No control group | TLP2×/day, 15 min./each, 5 days/wk. for 10 weeks +OT, ST, Spec. Ed., ABA | Auditory SOR(SensOR Scales; SPM)*(Client Factors)* | Based on the SensOR Scales, participant showed increased positive behaviors (tolerating & accepting auditory stimulus), and decreased negative behaviors (covering ears, startling reaction, rotating head away from stimulus) from initial to end phase; Both (HEA) subtest and the (TOT) of the SPM indicated improvements in auditory sensory processing and overall sensory processing | 16 Fair |
| Gee et al.,(2015) | Level IV<br>ABAB Multiple Events Case Control<br>*n* = 3, 34%Male, 66% Female<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (auditory sensory overresponsivity)<br>• Age 5–10 yrs.<br>No control group | TLP2×/day, 15 min./each, 5 days/wk.for 20 weeks; +OT, ST, Spec. Ed., ABA | Auditory SOR(SensOR Scales;SPM)*(Client Factors)* | Based on the SensOR Scales, increased to slightly increased positive behaviors (tolerating & accepting auditory stimulus) were noted in all 3 participants during the intervention phase B1 onlyBased on SensOR Scales, 2/3 participants showed decreased negative behaviors (covering ears, startling reaction, rotating head away from stimulus) in the intervention phase B1 only; no change in negative behavior was noted in 1/3 participants;Based on caregiver report on SPM (HEA & TOT), 1/3 participants had no change in auditory sensory processing and overall sensory processing, 1/3 participants showed improvement in both domains, 1/3 showed improvement only in auditory sensory processing | 18 Fair |

| | | | | | |
|---|---|---|---|---|---|
| Nwora and Gee (2009) | Level IV<br>Single Subject Case Study<br>*n* = 1, 100% Male,<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (sensory seeking, sensory sensitivity, poor registration)<br>• Age: 5 yrs.<br>No control group | TLP2 ×/day, 15 min./each, 5 days/wk.for 20 weeks +OT & ST | Sensory processing(SP) *(Client Factors)* | Improvements were noted in pre-to post intervention in all areas of the Sensory Profile except sensory seeking, fine motor and perceptual | 15 Fair |
| Schoen et al. (2015) | Level IV<br>Single subject non-concurrent multiple baseline AB design<br>*n* = 7, 57% Male, 43%Female<br>Inclusion Criteria:<br>• SPD: Sensory Modulation (tactile/auditory overresponsivity, sensory craving, sensory underresponsivity)<br>• Age 4–18<br>No control group | iLs 1×/day, 60 min., 5 days/wk. for 8 weeks (SBI only) | Individual parent goals: (VAS) Follows verbal directions, Follows multi-step verbal directions, Follows directions in a timely manner, Completes morning routine w/out incident, Completes spelling work in a timely manner, Completes writing assignments w/out emotional incident, Gets dressed in morning without incident, Has legible handwriting *(Performance Skills & Occupation-based)* | Based on the VAS, significant difference was noted from baseline goal performance to intervention phase across all participants, with *p* value at <0.001; In the BASC-2, attention, social, and communication subtests were not significant; In the ABAS-II, statistically significant changes were noted in communication subtest with p value = 0.02; subtests in social was not significant | 18 Fair |

*Note*. AIT = Auditory Integration Training; TLP = The Listening Program; iLs = Integrated Listening Systems; TL = Therapeutic Listening; ATEC = Autism Treatment Evaluation Checklist; ABAS–II = Adaptive Behavior Assessment System; BASC-2 = Behavior Assessment System for Children; DAP = Draw a Person Test; VAS = Visual Analog Scale; VMI = Visual Motor Integration; SensOR Scales = Sensory Over-Responsivity Scale; SPM = Sensory Processing Measure; SP = Sensory Profile; SSP = Short Sensory Profile; ABC = Aberrant Behavior Checklist; SRS = Social Responsiveness Scale, SSRS = Social Skills Rating System.

Short Sensory Profile (Brockett et al., 2014). The potential for confounding variables existed as occupational therapy services or other interventions were not explicitly stated in two of the three studies (Al-Ayadhi et al., 2013; Brockett et al., 2014).

Al-Ayadhi et al. (2013) conducted a Level III pretest/posttest design study using AIT with a sample of 72 children with moderate-to-severe ASD. Findings suggested improvements in sociability as result of AIT as measured by the Autism Treatment Evaluation Checklist (ATEC). The authors also reported improvements in social awareness, social cognition, and social communication skills based on the Social Responsiveness Scale (SRS) at three and six months follow-up. Both results were statistically significant with $p < 0.05$.

Vadivel and Missal (2014) examined the effectiveness of AIT using a Level II pretest/posttest quasi-experimental design with a control group of six children with ASD. The control group consisted of OT, sensory integration therapy, and special education. Improvements in all components of the ATEC, consisting of speech/language/communication, sociability, sensory and cognitive awareness, health/physical/behavior, were reported in both groups with $p < 0.05$ except the speech/language/communication component of the control group which was not significant ($p < 0.10$). The study did not use a true Berard AIT device but a modified AIT device from Addonuss Electronic Research Technologies in India which utilized ordinary integrated circuit and Indian-based electrical and electronics components.

Brockett et al. (2014) performed a Level IV retrospective chart review on 54 children with a variety of diagnoses including autism, auditory processing disorder, and attention-deficit disorder. In all the areas pertaining to sensory modulation, positive results of the AIT intervention were reported based on the Short Sensory Profile with $p < 0.01$. Researchers reported large effect sizes, sustained at three and six months follow-up in auditory filtering (0.88), and visual/auditory sensitivity (0.86) based on Cohen's (1988) classified effect sizes.

### *Integrated listening systems (iLs)*

According to the iLs developers, iLs influences attention and regulation, auditory processing, learning ability, reading skills, sensory processing, and speech (Integrated Listening Systems, 2017). iLs uses specific classical music selections to process and enhance specific frequencies of sound delivered through a mini amplifier with air or bone conduction headphones (Schoen et al., 2015). iLs is coupled with balance, movement, and visual-motor activities selected from the iLs playbook manual which are performed for 15–20 min at the beginning of the session.

One study included in this systematic review examined iLs (Schoen et al., 2015). Schoen et al. (2015) performed a Level IV single subject nonconcurrent multiple baseline AB design study. The iLs intervention consisted of 40 sessions of iLs with 60 min per session provided over an eight-week duration to a convenience sample of seven participants. Individualized family goals served as the outcome measures which included education-related activities of following directions verbally and with multi-steps, completing morning routines without incident, completing writing assignments without emotional incident, completing homework in a timely manner, completing spelling work in a timely manner, and having legible handwriting. The family goals were categorized into outcomes in following directions, completing a task, and fine

motor skills. A variety of assessment tools were utilized including the Visual Analog Scale (VAS), Adaptive Behavior Assessment System-II (ABAS-II), and the Behavior Assessment System for Children-2 (BASC-2; Table 2). Significant differences were noted from baseline performance to the intervention phase for all participants with $p < 0.001$ based on the VAS. Additionally, the ABAS-II and the BASC-2 was utilized as exploratory outcome measures in the study. Based on Cohen's (1988) classification, a moderate effect size (0.58) with $p < 0.02$ was reported in the communication subtest of the ABAS-II. The BASC-2 clinical subtest on attention did not produce significant results. The presence of therapy services including occupational therapy was an exclusion criterion for this study which decreased potential cointervention bias. Based on the Quality Index score, the Schoen et al. (2015) study scored an 18 (fair quality). Limitations of the study were limited sample size recruited through convenience sample, potential intervention bias as treatment occurred at both home and office settings, and self-reported bias in the parent completed outcome measures (Table 3).

### *Therapeutic listening*

Therapeutic Listening was developed by occupational therapist, Sheila Frick, to improve an individual's attention, timing, and sequencing of motor skills, irritability and mood, perception and navigation of space, regulation of energy levels, and motor planning skills (Vital Links, 2017). Therapeutic Listening uses electronically modified music to complement a sensory-based or sensory integration treatment approach (Vital Links, 2017). Therapeutic Listening consists of listening to modulated music and SAMONAS CDs 30 min twice daily for 3–6 months depending on the listener's needs.

Therapeutic Listening was utilized in two studies in this systematic review (Bazyk et al., 2010; Hall & Case-Smith, 2007). The Quality Index scores were both 21 (good quality; Table 2). Limitations of the studies included the use of convenience sampling, a heterogeneous sample with participants who had a variety of medical diagnoses, lack of a control group, and mixed frequencies of occupational therapy services or no occupational therapy services. In both studies, Therapeutic Listening was provided in conjunction with traditional school-based occupational therapy services for most study participants.

Bazyk et al. (2010) examined the effects of Therapeutic Listening with 15 preschoolers with developmental disabilities using a Level III preexperimental pretest/posttest study design. Hall and Case-Smith (2007) examined the effects of Therapeutic Listening using a multiple single-subject series design with 10 children with visual motor delays and SPD. Both Therapeutic Listening studies used standardized measures to evaluate performance skills that potentially contribute to a child's participation in education such as fine motor, visual motor, and social skills.

After implementation of Therapeutic Listening, children's social skills improved significantly as measured by the Social Skills Rating System, grasp and visual motor skills improved as measured by the Peabody Developmental Motor Scale-2nd edition (Folio & Fewell, 2000), and handwriting skills improved as measured by the total legibility subscale from the Evaluation Tool of Children's Handwriting (Amundson, 1995), all with $p < 0.05$. The Developmental Test of Visual Motor Integration (VMI; Beery, Buktenica, & Beery,

2004) composite score increased significantly in one Therapeutic Listening study (Bazyk et al., 2010), but in Hall and Case-Smith (2007), only the VMI visual perception subscale reached significance at $p < 0.05$. Improvements in children's sensory processing as result of the program were mixed in both studies. Hall and Case-Smith (2007) found children improved in sensory processing on 8/14 subtests ($p < 0.05$) as measured by the Sensory Profile (Dunn, 1999); however, Bazyk et al.'s (2010) study reported no significant changes in any Sensory Profile subtests.

### *The listening program (TLP)*

TLP addresses an individual's executive function, communication, auditory processing, social and emotional skills, stress response, and motor coordination (Advanced Brain Technologies, 2017). TLP consists of listening to acoustically modified instrumental music via air or bone conduction headphones. Depending on clients' needs, a variety of listening schedules are available which range from 15 to 30 min daily, five days a week, for 20 weeks.

Four Level IV studies in this systematic review utilized TLP (Francis, 2011; Gee et al., 2015, 2014; Nwora & Gee, 2009). Traditional and sensory-based occupational therapy services were provided in conjunction with TLP in all studies except Francis (2011) in which co-interventions were not specifically reported. The Quality Index score ranged from 15 to 19 (fair to good quality) based on the four studies which examined person engagement, auditory SOR, and overall sensory processing. Limitations of all four studies included: small participant sample needed for generalization of intervention, and lack of standardized assessment tools in measuring outcomes of interest. In two studies, there was potential bias in repeated outcome measures (Gee et al., 2014, 2015; Table 3).

Francis (2011) conducted multiple single case studies in a residential school for children with profound and multiple learning disabilities. Francis (2011) used the Profound Education Curriculum Profile, video recording and analysis, and observation recording as outcome measures. Findings suggested positive changes in the students' person engagement after TLP as compared to the placebo intervention of typical classical music. Based on the Education Curriculum Profile, eight of the 12 students also demonstrated a higher percentage of achievement on the students' individual educational plans as compared to the previous school year. Due to the lack of formal standardized assessment tool for this population, Francis (2011) did not report inferential statistics regarding the outcomes.

Three studies using TLP reported outcomes in sensory modulation and overall sensory processing. In Nwora and Gee's (2009) single subject case study, improvements were reported in major areas of sensory processing based on the Sensory Profile. Gee et al. (2014) and Gee et al. (2015) performed similar studies using participants with ASD and auditory SOR. TLP was utilized in an ABA single subject case-control in one study, and an ABAB multiple events case-control design with three participants in another study. Improvements were noted in auditory SOR and general sensory processing in Gee et al. (2014) study. However, in Gee et al.'s (2015) study, results in auditory SOR and general sensory processing were inconsistent among the three participants. Outcomes were

measured using the Sensory Over-Responsivity Scales (SensOR Scales) and the Sensory Processing Measure (SPM). $p$ values were not available in the studies.

## Discussion

Children with challenges in sensory processing and integration are at risk of experiencing difficulties participating in education due to occupational performance limitations related to challenges processing and interpreting sensory information in the context of a sensory-rich school environment. Many interventions exist for school-based occupational therapy practitioners to select in supporting children's participation in education. School-based therapists must use thoughtful procedural reasoning in determining interventions that will best meet individual children's educational objectives.

Sound-based interventions continue to be utilized in occupational therapy practice for children with challenges processing and integrating sensory information. This systematic review sought to examine the current evidence related to sound-based interventions for supporting children's participation in education for this population. No study explicitly measured participation-level outcomes in education. The findings of this review suggest limited preliminary published evidence to support the use of SBI's to improve performance skills and client factors relevant to participation in education for children with challenges in sensory processing. Evidence is limited due to methodological limitations within the studies, and some inconsistency in findings across individual studies (USPSTF, 2016). Published studies are increasing, including those with higher level experimental designs than identified in previous SBI systematic reviews by Sinha et al. (2006) and Sinha et al. (2011).

The 10 included studies examined four different SBI programs: Auditory Integration Training, Integrated Listening Systems, Therapeutic Listening, and The Listening Program. The Auditory Integration Training studies suggested overall improvements in children's sociability, social responsiveness, and sensory modulation specifically auditory filtering and visual/auditory sensitivity. The Integrated Listening Systems study reported improvement in children's communication skills. The Therapeutic Listening studies reported improvements in children's social skills. Finally, the Listening Program studies reported improvements in sensory modulation as well as engagement with others and improved IEP objective achievement.

### *Social skills and SBIs*

Social skills were consistently reported as an improved outcome for children across SBI programs within this systematic review (Al-Ayadhi et al., 2013; Bazyk et al., 2010; Francis, 2011; Vadivel & Missal, 2014). This finding aligns with previous evidence demonstrating the critical link between social skills and educational participation. Regarding academic educational participation, evidence indicates that social emotional competence predicts preliteracy performance in typically developing children (Curby, Brown, Hamada Bassett, & Denham, 2015), and for children with ASD, social and communication skills significantly predict academic achievement, especially reading comprehension (Miller et al., 2017). Evidence also suggests a link between social skills and nonacademic educational participation. Locke, Shih, Kretzmann, and Kasari (2016) highlighted that children with

ASD with decreased social skills spent approximately 30% of their recess time engaged in solitary play as compared to their typically developing peers who spent about 9% of their recess time in solitary play. Social skills also predicted consistent sports participation for both children with and without disabilities (Marquis & Baker, 2015) and in turn, children participating in after school sports and clubs demonstrated higher social skills (Howie, Lukacs, Pastor, Reuben, & Mendola, 2010). Given the consistent link between social skills and educational engagement across children with a variety of needs, future research of SBI programs explicitly measuring educational participation outcomes concurrent with social skill outcome measurement is warranted to determine SBIs potential contributions to educational participation through social skill development.

### Sensory modulation and SBIs

Most studies within this review reported improvement in children's sensory modulation abilities, specifically auditory filtering. Improved auditory filtering intuitively could improve a child's ability to filter salient auditory instructional and social information and in turn influence academic performance, social interactions, and educational participation. Previous literature identifies auditory sensitivity as negatively associated with academic performance for children with ASD (Ashburner et al., 2008). Additionally, some theoretical literature suggests sound sensitivity or auditory filtering may be associated with regulation of the muscles of facial expression, which could influence social engagement and interactions (Doman, 2008; Porges, 2001). However, no experimental research examining this specific correlation exists and further research examining this hypothesized correlation is needed.

Given occupational therapists' use of SBI programs for children with challenges in sensory processing and integration, the current limited findings underscore the need for occupational therapists to clearly define the targeted outcome of the SBI, ensure the outcome is occupation-based in support of school participation, and quantitatively measure the targeted outcome to determine the level of efficacy of the SBI for the individual child. Such outcome measurement will support occupation-based, ethical, and evidence-based practices when using SBI programs.

### Limitations

The included studies in this systematic review have inherent limitations which should be considered when evaluating the evidence for application to occupational therapy practice. First, many studies utilized descriptive or discriminative measures (e.g. Sensory Profile) in a manner for which the tool was not designed as pre/post-outcome measure and thus findings must be interpreted cautiously. Additionally, in many studies given the lack of a control group, randomization of treatment, and small sample sizes, findings cannot be directly attributed to the generalizable population. Additionally, only two of the 10 studies controlled for co-interventions with at least half of the studies including participants who received therapy services in addition to the SBI. Lastly, although researchers consulted with an experienced health science librarian to develop a thorough list of search terms for all databases, 21 articles were found through hand searches.

### Implications for practice

Findings of this review suggest SBI programs currently have limited preliminary evidence on outcomes related to participation in education including visual motor, fine motor, communication, and social skills of children with challenges processing and interpreting sensory information. Improvements noted as result of SBI programs specifically linked to improvements in a child's participation in education remains yet unstudied. SBI programs can be easily provided in home and school settings and these programs have the potential to support a child's everyday occupation of education.

This systematic review suggests the following implications for occupational therapy practice. First, occupational therapists should use caution in using SBI programs with the intent to improve a child with challenges in sensory processing and integration's educational participation due to limited evidence supporting this intervention for this population and outcome. Occupational therapists should identify explicit outcomes of interest the SBI is targeting and collect routine data to measure progress. Secondly, occupational therapy researchers should continue to examine the effectiveness of SBI programs; particularly, with inclusion of control groups and lack of co-interventions in research designs. Finally, occupational therapists using SBI's to improve educational participation for children with difficulties processing and interpreting sensory information should simultaneously measure both educational participation and targeted performance skills.

### Recommendations for future studies

The 10 studies included in this review measured a wide variety of SBI outcomes from auditory SOR to fine motor skills. Improvements in client factor and performance skill outcomes cannot be assumed to contribute to, nor correlate with improvements in children's participation in the occupation of education. Future research should incorporate outcome measures which directly measure both performance skills and participation in education simultaneously to determine correlations. Future SBI studies should also focus on improving research methods by incorporating a control group, randomizing interventions, increasing sample size recruitment based on statistical power calculations, and controlling for co-interventions. Lastly, future research should incorporate outcome measures specifically designed for evaluative purposes to support the rigor of findings.

## Conclusion

No single study in this systematic review explicitly measured participation-level outcomes in education as a result of a SBI for children with challenges processing and interpreting sensory information. However, 10 studies examined outcomes of relevance to the educational participation of children. The 10 studies indicate there is currently limited evidence in using SBIs supporting outcomes related to participation in education based on Level II to Level IV studies. Individual studies reviewed did report preliminary positive effects of SBI's on children's communication, social, fine motor, visual motor skills, sensory modulation, following directions, and completing a task suggesting the potential for SBIs to support education-related occupations for children with sensory processing and integration challenges. The effects of SBIs on improving children's sensory processing were mixed with three of five studies reporting positive effects, and two of five reporting no significant

improvements. Positive outcomes involving person engagement, following directions, completing a task, and sensory modulation were limited to Level IV study designs.

Occupational therapists using a SBI for children with sensory processing and integration challenges with the intent to support children's education-related occupations should use caution by openly educating clients about the risks and benefits of SBIs, following appropriate guidelines in application of the SBI, and by identifying and measuring clearly defined intervention outcomes. Future SBI research should include improved research methodological design by including a control group, randomizing treatment, increasing sample sizes to ensure adequate statistical power, controlling for co-interventions, and determining a specific set of outcome measures.

## Declaration of interest

We have no conflict of interest to declare.

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