SPECIAL ISSUE PAPER

Efficacy of a Sound-based Intervention with a Child with an Autism Spectrum Disorder and Auditory Sensory Over-responsivity

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Abstract

Sound-based interventions (SBIs) are being used by paediatric occupational therapists to help children with autism spectrum disorders and co-morbid sensory processing disorders. A limited yet growing body of evidence is emerging related to the efficacy of SBIs in reducing sensory processing deficits among paediatric clients with co-morbid conditions. The current study employed an ABA single-subject case-controlled design, implementing The Listening Program® with a 7-year-old child diagnosed with autism spectrum disorder who demonstrated auditory sensory over-responsivity (SOR). The intervention consisted of 10 weeks of psycho-acoustically modified classical music that was delivered using specialized headphones and amplifier and a standard CD player. Repeated measures were conducted during the A(1), B and A(2) phases of the study using the Sensory Processing Measure, a subjective caregiver questionnaire, and the Sensory Over-Responsivity Scales, an examiner-based assessment measure to track changes of the participant's auditory SOR-related behaviours. The results indicated that the participant exhibited a decrease in the number of negative (avoidant, verbal and physical negative) and self-stimulatory behaviours. The decreases in negative and self-stimulatory behaviour may have been due to the therapeutic effect of the repeated exposure to the Sensory Over-Responsivity Scales or The Listening Program SBI.

Received 8 January 2013; Revised 28 August 2013; Accepted 6 September 2013

Keywords

sound-based intervention; autism spectrum disorder; sensory over-responsivity

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Published online 29 October 2013 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/oti.1359

Introduction

Auditory sensory processing has been reported to be a significant sensory processing disturbance experienced by individuals with an autism spectrum disorder (ASD) (Tomchek and Dunn, 2007). Greenspan and Weider (1997) reported that 100% of the 200 participants in their study with ASD exhibited atypical responses to auditory sensory stimuli. Sensory processing requires a person to detect a sensory stimulus, modulate it, interpret it and respond to it. If the ability to perform any one the aforementioned components of sensory processing is impaired, there is typically a functional impact in the person's daily routine, and subsequently, a sensory processing disorder may be present. One subtype of sensory processing disorder is sensory modulation disorder (SMD), where problems arise in controlling the degree, intensity and nature of a child's responses to sensory stimuli; these problems may impact the child's functioning in every-day life activities (Miller *et al.*, 2007a).

Sensory over-responsivity (SOR) is a type of SMD, which is characterized by a quicker response to a sensation, "with more intensity, or for a longer duration than those with typical sensory responsivity" (Miller *et al.*, 2007b, p. 136). Individuals who exhibit the symptoms of SOR may experience behavioural challenges that "range from active, negative, impulsive, or aggressive responses to more passive withdrawal or avoidance of sensation" (p. 137). A single (i.e. tactile) or multiple sensory systems (i.e. tactile, auditory and olfactory) may contribute to the aforementioned aversive behavioural outcomes in children with SMD (Miller *et al.*, 2007b). Moreover, individuals who demonstrate SOR may be highly rigid and controlling during play, self-care and other routine developmental activities (Miller *et al.*, 2007b). In a study of 42 children with ASD, O'Donnell *et al.* (2012) reported a correlation between increased levels of sensory processing disturbances (e.g. sensitivity, under-responsiveness, seeks sensation, low energy and auditory filtering) and maladaptive behaviours (e.g. crying, irritability, agitation, stereotypic behaviour, hyperactivity, non-compliance, lethargy and social withdrawal).

In addition to behavioural disturbances, physiological differences have been found in children with high-functioning autism (HFA) and Asperger's syndrome (AS). These physiologic differences were reported by Schoen *et al.* (2008) using electrodermal activity in a sample of 40 children including those with HFA and AS. No statistically significant differences were found between the HFA and AS portions of the sample; therefore, they were assessed as a single group. On the basis of the results, the authors categorized the sample into two types of responses that included high arousal (i.e. faster habituation) and low arousal (i.e. slower habituation) to sensory stimuli regardless of their diagnosis of HFA or AS (Schoen *et al.*, 2008). In a sample of 25 children with ASD, Chang *et al.* (2012) identified a correlation between the caregiver's perception of auditory sensory over-responsiveness (e.g. covering ears, avoiding sounds or making verbal objections to sounds) and the over-activation of the sympathetic nervous system among the sample population, supporting the notion that there is a relationship between a child with ASD's autonomic activity to sounds and the behaviours related to auditory SOR reported by caregivers.

Auditory SOR, auditory hypersensitivity and hyperacusis have been defined synonymously within the literature as abnormal responses to sounds that are neither threatening nor uncomfortably loud compared with a typical individual's perception of sounds (Baguley, 2003; Bettison, 1996; Klein *et al.*, 1990; Miller, 2006). Using the Short Sensory Profile, Tomchek and Dunn, (2007) reported that among a sample of 400 children diagnosed with an ASD, 50.9% of children with ASD responded negatively to unexpected loud noises and that 45.6% of these children were reported or noted to hold their hands over their ears to avoid auditory stimuli.

Self-stimulatory behaviours and sensory processing disturbances

It has been suggested that repetitive self-stimulatory behaviours may be used as a coping strategy by children with ASD who demonstrate SOR (Liss *et al.*, 2006). Liss *et al.* conducted a descriptive study among 144 children with ASD and found that there was a distinct behavioural pattern that included over-reactivity, over-focusing and sensory-seeking behaviour among the sample. The authors tentatively postulated that some repetitive behaviours provide a predictable repetitive event for the child to attend to when placed in a context that they view as over-stimulating (Liss *et al.*, 2006). Boyd *et al.* (2009) demonstrated a direct association between SOR and repetitive behaviours through examiner-based structured observation and caregiver report. Specifically, Boyd *et al.* (2009) explored the relationship between ASD, hyper-responsiveness, hypo-responsiveness and sensory-seeking behaviours among 61 children with ASD. They reported a positive correlation between SOR and repetitive stereotypical behaviour among the participants.

Sound-based interventions

One avenue paediatric occupational therapists use to address auditory and other SOR-related behaviours in children and adolescents is SBIs (Bazyk *et al.*, 2010, Case-Smith *et al.*, 2008, Hall and Case-Smith, 2007; Nwora and Gee, 2009,). The Listening Program® (TLP; Advanced Brain Technologies, Ogden, UT, USA) is one of several SBIs used by paediatric occupational therapists to address behavioural disturbances related to sensory processing in children with ASD (Nwora and Gee, 2009; Gee *et al.*, 2013).

According to Advanced Brain Technologies (ABT, 2013), TLP uses psycho-acoustically modified classical music targeting certain frequency ranges that claim to impact functional capabilities including sensory processing, balance, learning, language, play and executive function. An individualized listening schedule is determined by the treating practitioner, usually with listening sessions occurring one to two times per day for 15 minutes per session for 5 days followed by a 2-day break. The listener listens to a series of 10 numbered CDs or tracks in numerical order over a 10-week period. After the first 10-week cycle, the listener reverses the order of the CD – starting with CD#10 and ending with CD#1 for a second cycle. A minimum of two cycles of listening is recommended by the manufacturer for the client to demonstrate moderate improvement (ABT, 2009). TLP uses a specialized set of headphones and a CD or MP3 player. Equipment costs for TLP run between $300.00–2,000.00 (ABT, 2009), yet TLP is typically not reimbursed through public or private insurance (Gee, *et al.*, 2013). Therapists who wish to become an authorized provider must complete a provider training through ABT (2013).

There is a paucity of peer-reviewed evidence supporting the use of TLP with children diagnosed with ASD; most information is anecdotal at the time of this study. In a single case study, Nwora and Gee (2009) reported mild to moderate improvement in behavioural and sensory tolerance in a 5-year-old child with pervasive developmental disorder using TLP. The improvements were determined by comparing pre-data and post-data through the Sensory Profile, the Listening Checklist and clinical observations. Thus, the purpose of this study was to determine if a 10-week sound-based auditory stimulation method reduced SOR to auditory stimuli and decreased self-stimulatory behaviour in a child diagnosed with an ASD.

Methods

Research design

Using routine audiological testing, examiner behavioural observations and caregiver questionnaires as repeatable measures, the researchers attempted to capture the response to intervention over a 10-week time frame, using an ABA single-subject controlled design (Deitz, 2006; Portney and Watkins, 2009).

Participant

A 7-year-old girl diagnosed with moderate ASD and her primary caregiver were recruited for the study. The participant was recruited from a local hospital outpatient rehabilitation clinic in the northwest portion of the United States. During the A(1), B and A(2) phases of the study, the caregiver was instructed to continue the child's participation in her routine educational and therapeutic interventions including special education, occupational therapy, speech therapy and applied behavioural analysis.

The participant was selected for the study on the basis of the following factors: 1) she was diagnosed with mild to moderate ASD; 2) she exhibited sensory over-responsiveness to auditory stimuli to the point that it was interrupting daily routines or roles (i.e. playing, social interaction, feeding, sleeping, self-help and self-regulation) as reported by her caregiver; 3) she tolerated wearing headphones for a minimum of 15 minutes in a single sitting two times per day; and 4) she was between 5 and 10 years age (as the Sensory Processing Measure [SPM] and the Sensory Over-Responsivity [SensOR] Scales are best suited for the aforementioned age range).

The instrumentation used in the study included the SPM (Parham et al., 2007b) and the SensOR Scales (Schoen *et al.*, 2008). The SPM is a judgement-based caregiver questionnaire that explores visual, auditory, tactile, proprioceptive and vestibular functioning, social participation and praxis. The measure has two portions: a home form and a school form. For the purpose of this study, only the home form was used. Within each domain, the SPM provides information on processing disturbances, specifically under-responsiveness or over-responsiveness, sensory-seeking and perceptual challenges (Parham et al., 2007a).

The SPM consists of 75 Likert-scaled questions, in which a caregiver judges his or her child's frequency of sensory processing-related behaviour as "never, occasionally, frequently or always." Typically, scores are calculated for each sensory processing domain subtest, and then, an overall score is generated. However, for the purpose of this study, only the hearing (HEA) and the overall total sensory processing score (TOT) were tracked. Scores are then interpreted as being typical, having some problems or demonstrating definite dysfunction (Parham et al., 2007a). The SPM has a reported test–retest reliability of 0.77–0.95 and the evidence of validity through expert review and factor analysis (Parham *et al.*, 2007a).

The SensOR Scales is an examiner-based observation measure that evaluates a child's sensory over-responsiveness in the sensory domains of tactile, vestibular, proprioceptive, gustatory/olfactory, visual and auditory (Schoen *et al.*, 2008). This measure is administered through an examiner who documents a client's response to a given sensation for each sensory domain. The SensOR Scales has a concurrent validity of 0.47–0.74 and an interrater reliability of 0.75 (Schoen et al., 2008). For the purpose of this study, the authors only assessed the participant's auditory domain.

The SPM and the SensOR Scales have yet to yield test–retest reliability used as a part of a repeated measure design within the literature. Thus, caution is warranted regarding the reliability and stability of each of the repeated scores on the SPM and the SensOR Scales across all phases of this study.

Beyond sensory processing-related behaviours that were measured through the SPM and the SensOR Scales, self-stimulatory behaviours were documented as a part of the study. The participant's self-stimulatory behaviour was observed by the examiners and later verified by the caregiver during the A(1) phase. The behaviour that was labelled and tracked as self-stimulatory was the participant's visual gaze moving her iris into the left quadrant of her visual field without rotating her head outside of 0–10°. The participant's self-stimulatory behaviour was tracked using two quantifying methods; first, by identifying the number of times the behaviour occurred during the SensOR Scales and secondly by timing the duration of the behaviour using a standard stopwatch.

Procedures

Permission to conduct the study was granted by the Human Subjects Committee at Idaho State University. Once informed consent was obtained, the participant took part in routine audiological screening and assessment conducted by a licensed audiologist. Otoscopy, which is a visual examination of the ear, was performed and ruled out the presence of excessive wax and other outer ear disorders in the participant. A GSI TympStar (Eden Prairie, MN, USA) was used to assess for middle ear function and ruled out the presence of any middle ear pathology. To evaluate cochlear function and hearing sensitivity, distortion-product otoacoustic emissions and puretone threshold testing were attempted but not completed because of participants' cognitive and social limitations. The loudness discomfort levels test was attempted prior to the A(1) phase but could not be completed because of the participant's cognitive and social limitations; therefore, the loudness discomfort level was not re-attempted in the A(2) phase.

The purpose of phase A(1) was to establish the participant's baseline response to auditory sensory stimuli. Phase A(1) was composed of four weekly sessions, 1 day per week, which were conducted at the university-based outpatient clinic. Each session lasted for approximately 20 minutes. Following each phase A (1) session, the caregiver completed the SPM in one room of the clinic, whereas the examiner administered the SensOR Scales to the participant in another area of the clinic. This assessment requires the administrator to observe the participant for behaviour while various sounds are presented. The participant is engaged in various tasks including identifying the sounds (vacuum, blender, siren, clock, barking dog and a buzzing bee), blowing a whistle and playing a cymbal in time to the music. The behavioural classifications for the observations can be found in Table 1.

The B phase was initiated with the introduction of the TLP auditory stimulation method. The participant listened to psycho-acoustically modified classical music for 10 weeks (one cycle), two times per day, 5 days per week, for 15 minutes each listening session (refer to Table 2). The intervention was carried out at home by the participants' caregiver, without the presence of the therapist. On the basis of the time and resources of the investigators and the availability of the participant, the intervention phase was limited to 10 weeks (one cycle) as opposed to the 20 weeks of intervention recommended by the

Table 1. Behavioural classifications for observations for the Sensory Over-Responsivity Scales

Behavioural classifications for observations for auditory sensory over-responsiveness	
Negative behaviours	Positive behaviours
Startling to the stimulus	Accepting stimulus
Eliminating the stimulus	
Demonstrating a physically negative response to the stimulus	
Verbalizing a negative perception to the stimulus	

Table 2. B phase intervention sequence

B phase treatment	Week 1	Week 2	Week 3	Week 4	Week 5
TLP album	Full spectrum	Sensory integration	Sensory integration	Sensory integration	Speech and language
Frequency range (Hz)	20–20,000	0–750	0–750	0–750	750–4,000
B phase treatment	Week 6	Week 7	Week 8	Week 9	Week 10
TLP album	Speech and language	Sensory integration	Sensory integration	Sensory integration	Full spectrum
Frequency range (Hz)	750–4,000	0–50	0–750	0–750	20–20,000

TLP = The Listening Program.

manufacturer. The SBI (TLP) was delivered through the use of a CD player, an amplifier and headphones retrofitted with a bone conductor (ABT Bone Conduction Audio System™; Advanced Brain Technologies, Ogden, UT, USA). Bone-conducted listening was selected because the manufacturers of TLP claim that this type of listening "supports stress reduction and regulation of the 'fight or flight' response, to help achieve a state of calm and relaxed/alertness; especially helpful for people with sensory sensitivities" (ABT, 2013, line 4).

On four occasions during the B phase (at weeks 2, 5, 8 and 10), the caregiver and the participant were asked to return to the clinic to complete the SPM and the SensOR Scales. However, the sequence of the auditory stimuli presented as a part of the SensOR Scales was randomized in an effort to limit the participant's habituation to test items. At the end of the B phase, the caregiver completed a brief questionnaire to ascertain if there have been any major changes to the child's pre-existing educational or therapeutic intervention programmes (i.e. frequency, intensity and duration of the interventions); the caregiver reported there had been no changes in the provision of services for the participant.

At the end of the B phase (10 weeks of TLP intervention), the participant discontinued listening to the TLP intervention programme and returned to the clinic to complete the A(2) phase, which entailed four subsequent weekly observation sessions to assess the participant's response following the cessation of the intervention. All 12 of the SensOR Scales observation sessions were video recorded and later scored by two raters (the primary investigator and a graduate research assistant). After each observation was completed, the primary investigator met with the caregiver to answer any questions and/or to exchange the TLP CDs during the B phase.

The A(2) phase consisted of the same procedures and measures that occurred during the A(1) phase to assess changes that may have occurred as a result of the intervention delivered during the B phase.

Results

Data were analysed using repeated measure graphs noting any changes in the level and direction of the trend lines (Deitz, 2006) for the SPM, the SensOR Scales and the frequency and duration of the participant's self-stimulatory behaviour.

Sensory Over-Responsivity Scales

The scores on the auditory domain of the SensOR Scales across the A(1), B and A(2) phases trended in an upward direction for positive behaviours (e.g. tolerating or accepting the auditory stimulus) and conversely in a downward direction for negative behaviours (e.g. covering ears, rotating head away from stimulus and startling reaction; Figure 1). Improvement in scores began during the A(1) phase and continued in the B and A(2) phases of the study. Although there appeared to be preliminary improvement in scores on the SensOR Scales in A(1), this pattern was not optimal given the study design; one would not expect to see any change in behaviour during this phase as treatment had not yet begun.

Sensory Processing Measure

The *t*-scores on the auditory processing domain subtest (HEA) and the TOT of the SPM were tracked. Both scores trended in directions across the A(1), B and A (2) phases that are indicative of the improvement with auditory sensory processing and overall sensory processing. Higher *t*-scores are an indicator of the caregiver's perception of the child's increased difficulty with the sensory domain. The caregiver perceived the participant's auditory sensory processing as more severe during the first four observations within the A(1) phase. The scores and trend lines then began to decrease during the B phase and into the beginning of the A(2) phase. The caregiver perceived that the participant's HEA and TOT processing abilities began

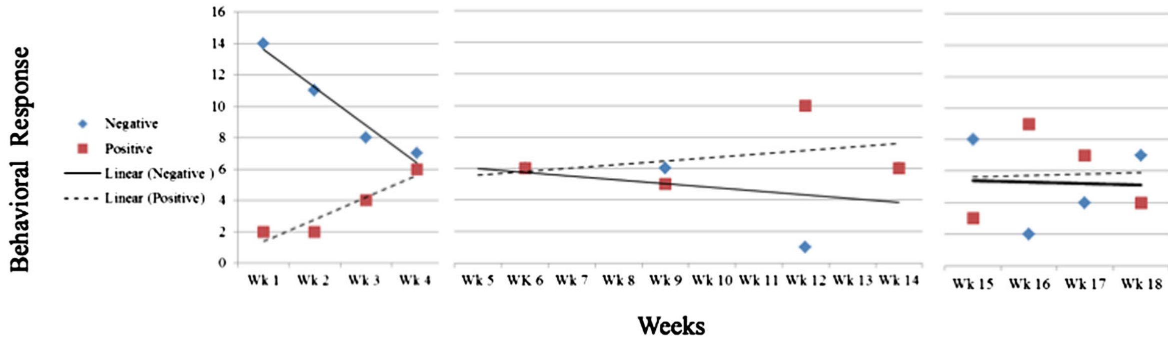

Figure 1. Sensory Over-Responsivity Scales

to worsen once the intervention was withdrawn. The change in the trend lines across all three phases may be an indication of the influence the intervention had upon the participant during daily activities (refer to Figure 2).

The frequency and duration of self-stimulatory behaviour were tracked and measured across all three phases of the study through indirect examiner observation that occurred during the administration of the SensOR Scales. The authors identified a visual self-stimulatory behaviour within the participant's repertoire of behaviours when she was exposed to certain auditory stimuli, which were then tracked as a part of the study. This particular behaviour was later confirmed by the caregiver as a self-stimulatory behaviour that was observed in variety of contexts and that this self-stimulatory behaviour frequently disrupted her participation in meaningful occupations.

The data related to self-stimulatory behaviours trended downward across the A(1) and B phases, with the most significant downward trend occurring during the second half of the B phase where the participant did not demonstrate the self-stimulatory behaviour during the observation sessions. Between the B phase and the A(2) phase, the trend lines shifted in opposite directions with self-stimulatory behaviours slightly increasing during the A(2) phase following the removal of the intervention (refer to Figure 3). Yet, the noted increase in duration and frequency of self-stimulatory behaviours were still shorter and less frequent than what had occurred in the A(1) phase. The intervention did appear to be having an effect on improving auditory and overall sensory processing and reducing self-stimulatory behaviour.

Discussion

The purpose of this study was to determine if a 10-week sound-based auditory stimulation method reduced SOR to auditory stimuli and decreased self-stimulatory behaviour in a child diagnosed with ASD. The results of this case study have several implications that may inform paediatric occupational therapy practice.

The participant's performance on the SensOR Scales was not an indicator of an overall improvement in auditory SOR. However, the caregiver did perceive that

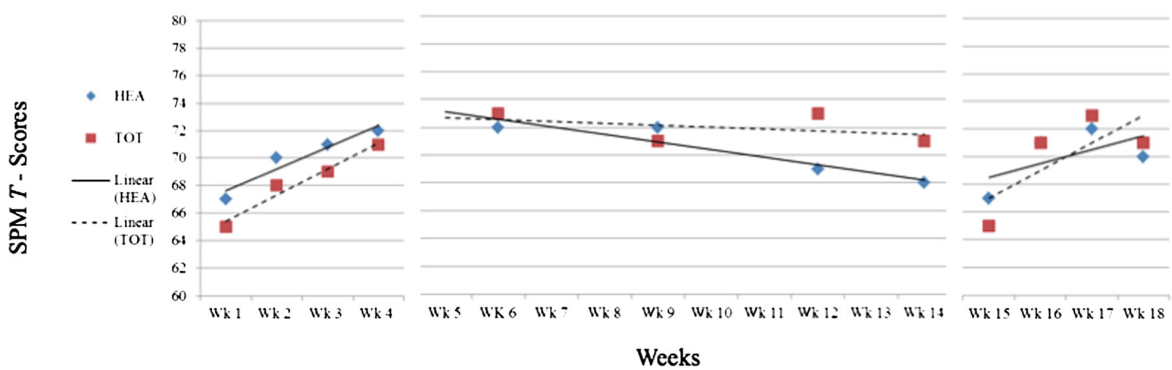

Figure 2. Sensory Processing Measure (SPM). HEA, hearing; TOT, total sensory processing score

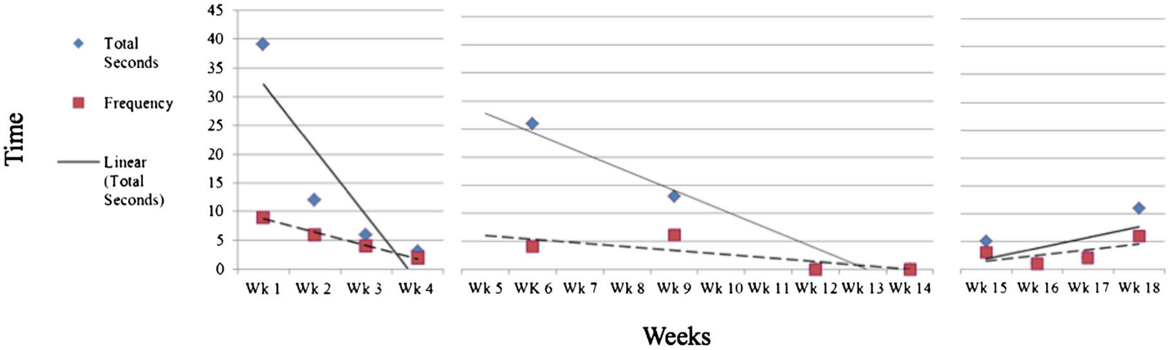

Figure 3. Self-stimulatory behaviour

the participant's auditory SOR did improve during the intervention portion (B phase) of the study as indicated by the *t*-scores on the HEA and TOT sections. Notable changes in the direction and level of the trend lines were noted prior to, during and when the intervention was withdrawn. This directional change is consistent with findings from other studies using a caregiver judgement-based questionnaire measuring the contextual impact of sensory processing on a paediatric client's functional capacities (Hall and Case-Smith, 2007; Nwora and Gee, 2009).

Caution is warranted, however, as there may be two plausible explanations for these results. The first was the accuracy with which the caregiver gave in her description of how the participant was demonstrating improvement in her response to contextual auditory stimuli during daily routines as reported on the HEA and TOT sections on the SPM. Another possible explanation may be that because of the study's design, the caregiver was not blinded to when the participant was exposed to the intervention and when it was withdrawn. Thus, the caregiver may have unknowingly displayed a bias towards the intervention, and a Hawthorne effect was the result. Ultimately, it is difficult to ascertain which of these explanations best represents the caregiver's interpretation of the effect that TLP was having upon the participant's auditory SOR. We had originally hypothesized that there would be a change in direction, specifically with an increase in negative behaviours and a decrease in positive behaviours on the SensOR Scales during the A(2) phase. However, there is support to suggest that a compounding influence may be present because of the repeated exposure of the auditory stimuli as a part of the SensOR Scales. Specifically, the measure itself may have been having a therapeutic effect upon the participant's auditory SOR. This finding is significant and may be an indicator that systematically exposing a client to sounds that vary in volume and frequency may be just as effective as an SBI. This finding also supports the results generated by Koegel *et al.*, (2004), who developed a non-music sound-based hierarchal desensitization intervention programme for three children with ASD. Koegel *et al.* reported observing a significant decrease in sensory over-responsiveness among the three participants as a result of the intervention, which presented a hierarchy of sounds (i.e. vacuum, blender and hand mixer) over a 24-week period of exposure.

This is the first study that has attempted to capture whether a home-based sound-based intervention programme may impact the self-stimulatory behaviour of an individual with an ASD. It may be plausible to hypothesize that the participant's self-stimulatory behaviour was a mechanism to reduce or "manage" her sensory over-responsiveness to auditory stimuli. This observation falls in line with the hypothesis of Liss *et al.* (2006) who reported that children with ASD who engage in self-stimulatory/repetitive behaviours may be a coping mechanism when experiencing sensory over-responsiveness.

The participant demonstrated a significant reduction in the frequency and duration of self-stimulatory behaviours during the A(1) and B phases to the extent that there were no self-stimulatory behaviours observed during the last two observations and only a minimal increase in self-stimulatory behaviours during the A(2) phase. This provides preliminary evidence suggesting a positive effect of TLP with this participant.

Study limitations

There are several limitations in this single case study, which prevent the generalization of the results of this study to the broader population of children with an ASD who also demonstrate auditory SOR and self-stimulatory behaviour. The manufacturer of TLP recommends 20 weeks of continuous auditory stimulation, yet we implemented the auditory stimulation for 10 weeks. English was a second language for the caregiver of the participant and may have impacted the caregiver's understanding of some of the questions within the SPM. The caregiver and the examiners were not blinded to evaluation procedures. Because of time constraints, the researchers were unable to obtain stable data reflecting a flat or directional trend line for phase A(1). It may also be argued that the participant began to habituate to the test stimuli of the SensOR Scales during the A(1) phase. Either way, the testing effect that seemed to be present in regard to auditory SOR may have masked the impact the intervention may have been having upon the participant's auditory SOR. Finally, the SPM and the SensOR Scales both lacked the test–retest reliability necessary for a repeated measure design, thus may have not have been stable measures to represent change over time.

Recommendations for future research

Further research is needed to explore the efficacy of the more contemporary sound-based (e.g. TLP, Integrated Listening Systems, Therapeutic Listening) interventions that paediatric occupational therapists are using within clinical practice. We suggest that a second B phase be added to the aforementioned used design to observe whether a second intervention phase may possibly reduce auditory SOR. The SensOR Scales presented stimuli that were pre-recorded and clinically simulated reproductions of altering sounds, which may not have best represented a typical auditory landscape the participant functioned in. Therefore, developing tools to an individual's auditory SOR within a natural context is recommended. This may help determine whether future participants may be habituating to the measurement tool or actually experiencing a reduction with auditory SOR.

We recommend implementing TLP across 20 continuous weeks as recommended by the manufacturer of TLP. It is the authors' opinion that sensory-based interventions, which TLP may be classified as, should be used as a part of a comprehensive occupational therapy using a sensory integrative approach (OT-SI) as opposed to a stand-alone intervention outside of OT-SI. Although improvements were noted in the participant's overall sensory processing-related behaviour, incorporating sound-based intervention into OT-SI may yield positive outcomes within multi-sensory systems as opposed to a single sensory system.

Acknowledgements

The authors would like to thank the Department of Physical and Occupational Therapy of Idaho State University, the Sensory Processing Disorder Foundation, Advanced Brain Technologies and Wal-Mart for providing additional funding, materials and supplies and the space to conduct the case study.

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