The effectiveness of auditory stimulation in children with autism spectrum disorders: A case–control study

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Background/Aim: *The Listening Program (TLP) is a sound-based intervention that claims to treat the behavioural challenges of children diagnosed on the autism spectrum with sensory processing difficulties. There is a paucity of peer-reviewed evidence supporting its use. The purpose of this study was to determine whether TLP reduces sensory over-responsivity (SOR) to auditory stimuli.*
Methods: *Data were collected over a 28-week period using an ABAB multiple events case–control design of testing and treatment intervals to capture the responses of three participants to TLP.*
Results: *Graphs from repeated measures data were drawn to analyse the direction and level of trend lines. There was a high variability of responses, with participants responding positively and others negatively at different stages of the study.*
Conclusions: *The results lend some support to the use of TLP with children on the autism spectrum who are experiencing auditory SOR.*

Key words: ■ Sound-based interventions ■ Autism spectrum disorders ■ Occupational therapy ■ Sensory over-responsiveness ■ Sensory processing ■ The Listening Program

Submitted 1 July 2014; sent back for revisions 10 September 2014; accepted for publication following double-blind peer review 18 November 2014

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Sensory processing disturbances within the auditory sensory system are a substantial problem experienced among individuals with autism spectrum disorders (ASD) (Greenspan and Weider, 1997; Kern et al, 2006; Tomchek and Dunn, 2007). Occupational therapists frequently use sound-based interventions for children with ASD (Gee et al, 2013); however, the body of evidence supporting the use of The Listening Program (TLP), a sound-based intervention, in children diagnosed with ASD and sensory over-responsiveness (SOR) is limited. This study explores the potential outcomes related to the use of TLP with three children diagnosed with ASD and auditory SOR.

Sensory processing requires an individual to detect incoming sensory stimuli, determine its meaning, and generate a response consistent with the context (Miller, 2006). If an individual demonstrates an inability to perform any one of the aforementioned components of sensory processing, they may have a sensory processing disorder (SPD). SOR is a subtype of SPD that makes it difficult for a person to process and use information they receive through their senses. The person may over- or under-respond to one or more forms of sensation. As a result, the person may have difficulty completing everyday tasks, which results in behavioural problems, emotional problems, and occupational performance problems in self-care, play and school activities (Miller et al, 2007a).

SOR is characterised by a rapid response to a sensation from any of the eight sensory systems—tactile, vestibular, visual, auditory, proprioception, interoception, gustatory and olfactory—'with more intensity, or for a longer duration than those with typical sensory responsivity' (Miller et al, 2007b: 136). The literature defines auditory SOR as abnormal responses to sounds that are neither threatening nor uncomfortably loud for a typical individual (Klein et al, 1990; Bettison, 1996; Baguley, 2003).

Estimates place the prevalence of comorbidity of ASD and SPD at 69–95% (Baranek et al, 2006; Tomcheck and Dunn, 2007). Auditory SOR appears to be common among children diagnosed with ASD. In a retrospective study, Greenspan and Wieder (1997) reported that 100% of children (*n*=281) with ASD presented with disturbances in auditory processing. These auditory processing disturbances specifically related to receptive language and resulted in

the children exhibiting abnormal responses to auditory stimuli, which affected their daily routines. Tomchek and Dunn (2007) reported similar evidence of a relationship between auditory SOR and ASD. In their study on children (*n*=281; age range: 3–6 years) with ASD, 50.9% responded negatively to unexpected loud noises and 45.6% held their hands over their ears to protect themselves from sounds. Baranek et al (2006) demonstrated the relationship between other types of SOR and ASD, finding that 56% of children (*n*=281; age range: 2–7 years) with ASD demonstrated extreme SOR to environmental sensations.

The literature suggests that auditory SOR among individuals with ASD may relate to several factors. These include:

■ Serotonin dysfunction (reduction), which results in difficulty with sensory inhibition (Hitoglou et al, 2010)
■ Abnormalities in neurological thresholds (Tharpe et al, 2006)
■ Short conduction time in auditory brainstem response (Thabet and Zaghloul, 2013)
■ General emotional dysregulation (Prizant et al, 2000; Stiegler and Davis, 2010).

Most interventions that aim to reduce auditory SOR or hyperacusis focus on increasing an individual's ability to habituate to auditory signals (Stiegler and Davis, 2010). Specific interventions have included sound-based interventions and behavioural systematic desensitisation (Koegel et al, 2004). The literature suggests interventions such as:

■ Using rewards to reduce behaviours (Stiegler and Davis, 2010)
■ Self-talk and co-regulation strategies to help the individual deal with negative hyperacusis-related behaviours (Prizant et al, 2003)
■ Eliminating auditory protection devices.

Sound-based interventions and sensory over-responsiveness

Paediatric therapists and educators commonly use sound-based interventions to lessen auditory and other SOR in children and adolescents (Hall and Case-Smith, 2007; Case-Smith and Arbesman, 2008; Nwora and Gee, 2009; Bazyk et al, 2010; Francis, 2011; Gee et al, 2013; Gee et al, 2014). Several types of sound-based interventions can be employed by paediatric therapists and educators. One such intervention is The Listening Program (TLP) (Advanced Brain Technologies, 2014), which has been used to treat behavioural challenges experienced by children with chronic behavioural disorders and sensory processing difficulties (Nwora and Gee,

2009; Francis, 2011; Gee et al, 2013; Gee et al, 2014). Gee et al (2013) conducted a survey of occupational therapists and reported that the majority of respondents indicated routinely prescribing a sound-based intervention for clients diagnosed with ASD, Asperger's syndrome, attention deficit disorder and SPD.

Advanced Brain Technologies (2014) claims that TLP reduces sensory sensitivity through the use of psychoacoustically modified classical music to target frequency ranges that may impact functional capabilities, including: social and emotional regulation; balance; learning; language; play; and executive functions. The treating practitioner develops an individualised listening schedule, with listening sessions one to two times per day for five days, followed by a two-day break. A minimum of 20 weeks of listening is recommended for the client to demonstrate moderate change. The programme requires the use of specialised headphones that afford bone conduction and a CD player or digital audio device.

It is hypothesised that TLP may improve auditory SOR through gradual exposure to low (0–750 Hz), mid-range (750–4000 Hz) and high sound frequencies (4000–8000 Hz) (Advanced Brain Technologies, 2014). Graded exposure to these frequencies may help children who experience auditory SOR to gradually habituate to frequencies they experience as threatening or noxious. This habituation is posited to occur through the psychoacoustically modified classical music in the programme.

While peer-reviewed evidence supporting the use of TLP for children diagnosed with ASD is scarce, the body of literature on this topic is gradually growing. In a case study of a five-year-old child with pervasive developmental disorder, Nwora and Gee (2009) reported mild to moderate improvements in behavioural and sensory tolerance after using TLP as an adjunct to biweekly consultative occupational therapy. The improvements were determined by comparing pre- and post-observation data through structured questionnaires and an analysis of unstructured clinical observations. In another study using an ABA case–control single-subject design to investigate the effects of TLP on a seven-year-old child with moderate ASD, Gee et al (2013) reported improvements in the auditory domain of the Sensory Processing Measure (SPM) (Parham et al, 2007a) and reduced negative behaviours on the Sensory Over-Responsivity (SensOR) scales (Schoen et al, 2008). The authors also reported that the child demonstrated a reduced number and duration of self-stimulatory behaviours.

Case study

Table 1. ABAB case–control research design				
	A(1)	B(1)	A(2)	B(2)
Activity	Baseline testing	TLP intervention	Baseline testing	TLP intervention
Duration	4–5 weeks	10 weeks	4–5 weeks	10 weeks
TLP: The Listening Program				

Table 2. Description of the participants			
	Case A	Case B	Case C
Diagnosis	High-functioning autism	Moderate autism	High-functioning autism
Age	8 years, 7 months	6 years, 5 months	5 years, 4 months
Gender	Male	Female	Female

A study conducted by Francis (2011) reported positive changes as a result of using TLP in a sample of ten heterogeneous participants who had profound and multiple learning disabilities. Using a pre- and post-test design, Francis (2011) concluded that the participants demonstrated higher outcomes with the TLP intervention compared with regular music. Additionally, Francis (2011) reported that participants who were most likely to experience positive outcomes were those who also demonstrated difficulties with sensory processing during routine functional or contextual tasks. This and the above-mentioned studies that explicitly explored the effects of TLP were peer-reviewed and conducted independently of TLP manufacturers and distributors.

METHOD

Research design

This study aimed to determine whether the use of a sound-based intervention would reduce SOR to auditory stimuli in three children who had been diagnosed with ASD and auditory SOR. Examiner behavioural observations and caregiver questionnaires were used as repeated measures. An ABAB multiple events case–control design of testing and treatment intervals was used over a 28-week period to capture participants' responses to the intervention (Portney and Watkins, 2009). The research design consisted of four phases: 4–5 weeks of baseline testing (A(1)), followed by 10 weeks of the intervention (A(2)), then another 4–5 weeks of baseline testing (B(1)) followed by a final 10 weeks of the intervention (B(2)) (*Table 1*).

Description of the participants

Three participants who had been diagnosed with mild-to-moderate ASD were enrolled in the study (*Table 2*). The participants were recruited from a local hospital outpatient rehabilitation department and community-based clinics in a rural area of the Northwestern United States. All participants demonstrated auditory SOR that negatively interfered with their daily routines.

This study was approved by the Idaho State University Human Subjects Committee (application number 3035MOD2). Each of the three participants' legal guardians consented on their behalf for them to participate in this study. During each phase of the study, the caregiver was instructed to continue their child's participation in routine educational and therapeutic interventions; this included special education, occupational therapy, speech therapy and applied behavioural analysis.

The participants were selected for this study based upon the following inclusion criteria:

- A diagnosis of mild to moderate ASD
- The ability to tolerate headphone use for a minimum of 15 minutes in a single sitting twice a day
- Aged 5–10 years
- The presence of SOR to auditory stimuli that is reported by the primary caregiver as severe enough to interrupt daily routines or roles, e.g. playing, social interaction, feeding, sleeping, self-help and/or self-regulation.

Instrumentation

Testing measures for the study included the SPM and the SensOR scales. The SPM is a judgement-based, caregiver questionnaire that evaluates the following factors relating to a child's functional participation and performance at home, school and in the community (Stewart, 2010):

- Visual, auditory and tactile sensory processing
- Proprioception
- Vestibular functioning
- Social participation
- Praxis and ideas.

The SPM comprises a home and a school reporting form. For the purpose of this study, only the home form was completed. The SPM provides information within each sensory domain related to processing disturbances, specifically under-responsiveness, over-responsiveness, sensory-seeking and perceptual challenges (Parham et al, 2007a). This study used the SPM to capture the caregiver's perspective of their child's ability to function and participate in diverse contexts with varying sensory processing difficulties.

The SPM consists of 75 Likert-type questions. Each question asks the caregiver to rate the frequency of their child's sensory processing-related behaviour as 'never', 'occasionally', 'frequently' or 'always'. For the purpose of this study, the only scores calculated and tracked were the audi-

tory sensory processing (HEA) subtest and an overall total sensory processing score (TOT). Scores were then interpreted within the HEA subtest and TOT score 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 a high rate of validity generated through expert review and factor analysis (Parham et al, 2007b). However, at the time of the study, no literature could be found documenting the reliability of the SPM when used as a repeated measure.

The SensOR scales are examiner-based observation rating measures that evaluate a child's over-responsiveness in the sensory domains: tactile; vestibular; visual; auditory; proprioception; gustatory; and olfactory (Schoen et al, 2008). This measure is administered through an examiner who documents the client's response to a given sensation for each sensory domain. In this study, throughout each observation session, each participant was engaged in tasks that included: matching a sound (played from a CD player) to a picture on a worksheet; visually scanning and marking pictures and symbols while an auditory stimulus played in the background; and blowing a whistle or playing a cymbal in time to music. All the auditory stimuli were presented to the participant via a CD player with the volume set at 85 decibels. *Table 3* shows the categories used to classify participant response to the stimuli.

The SensOR scales have a validly of 0.67 and a reliability of 0.75 (Schoen et al, 2008). At the time of this study, no literature existed that detailed the reliability of the SensOR scales as a repeated measure. For the purpose of this study, the authors only evaluated the auditory domain.

Procedures

Once informed consent was obtained, participants completed a routine audiological evaluation, which was conducted by a licensed audiologist. The assessments ultimately ruled out the presence of excessive earwax, outer ear disorders and any middle ear pathology. The cochlear function of all three participants was determined to be within normal limits. A modified Loudness Discomfort Level (LDL) test was attempted with each participant prior to phase A(1). However, reliable and consistent results were not obtained due to the participants' cognitive and social limitations. As a result, the LDL test was not re-attempted at the end of phase A(2).

Phase A(1) aimed to establish the participants' baseline response to auditory sensory stimuli on the SensOR scales. Phase A(1) comprised four to five weekly sessions that were conducted at the

university-based outpatient clinic. Each observation session lasted approximately 20 minutes. During each session, the caregiver completed the SPM questionnaire in one room of the clinic while the examiner administered the SensOR scales to the participant in a separate area of the clinic to reduce the possibility of caregiver bias. The same caregiver completed the SPM questionnaire during all four phases of the study. The SensOR scales required the administrator to observe the participant's behaviour while various auditory stimuli were presented to them.

The B(1) phase initiated the TLP intervention. Participants listened to 15-minute sessions of psychoacoustically modified classical music twice a day, five days per week for ten weeks in their home environment (*Table 4*). Caregivers were given instructions to have the participant engage in preferred play or functional activities during their listening sessions. These activities included colouring, assembling puzzles and playing with Lego. The TLP intervention was delivered through a CD player, amplifier and headphones retrofitted with a bone conductor. The auditory stimuli was simultaneously transmitted via both air and bone conduction. Advanced Brain Technologies (2014) states that bone-conducted 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'.

On four occasions during the B(1) and B(2) phases (at Weeks 2, 5, 8 and 10), the caregiver and participant were asked to return to the clinic to complete testing (i.e. re-administration of the SPM and SensOR scales). The sequence

Table 3. Behavioral classifications of participant response to auditory stimuli
Negative behaviours
Startling to the stimulus
Eliminating the stimulus
Demonstrating a physical negative response to the stimulus
Verbalising a negative perception to the stimulus
Positive behaviours
Accepting the stimulus

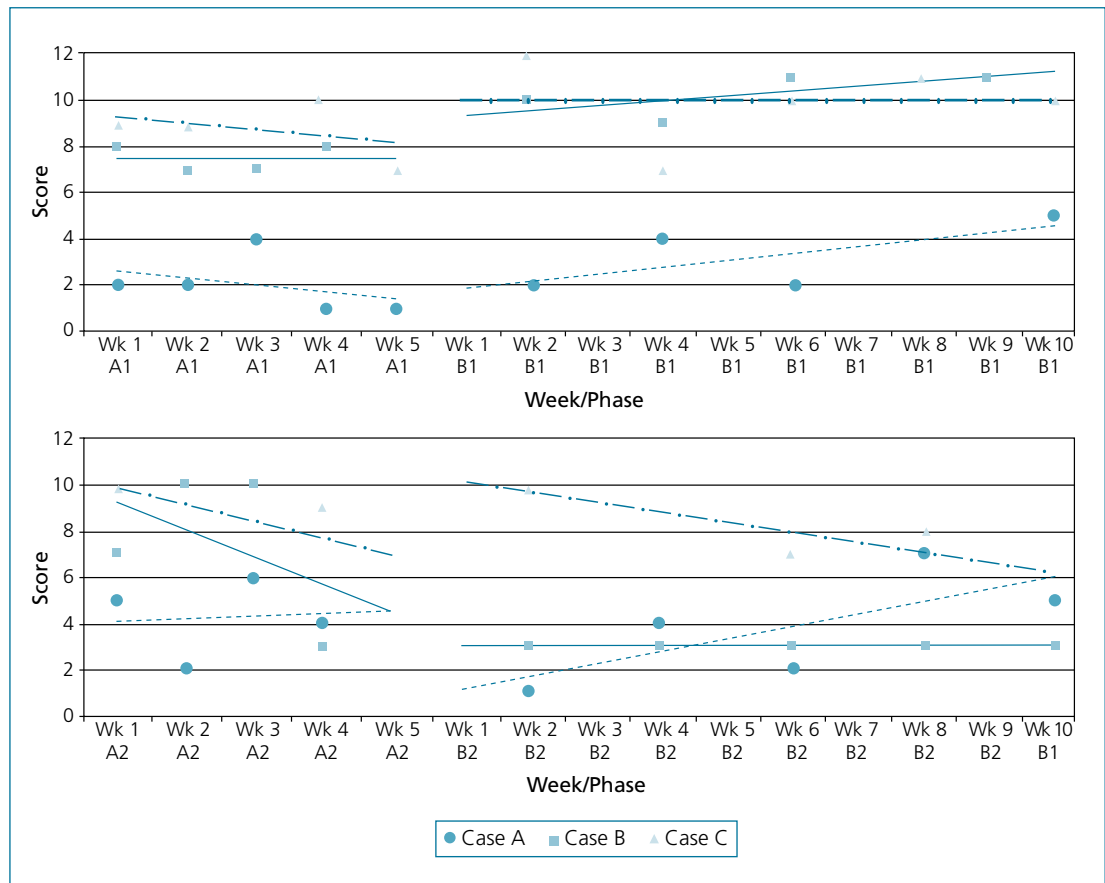| Table 4. Phase B intervention sequence		
	CD used from The Listening Program	**Frequency range**
Week 1	Full spectrum	20–20 000 Hz
Weeks 2–4	Sensory integration	0–750 Hz
Weeks 5–6	Speech and language	750–4000 Hz
Weeks 7–9	Sensory integration	0–750 Hz
Week 10	Full spectrum	20–20 000 Hz

Figure 1. Sensory Over-Responsivity scales—positive behaviours

of the tasks in which the auditory stimuli were presented during the re-administration of the SensOR scales was randomised using the Microsoft Excel number generator to limit participant habituation to test items. At the end of the B phase, the caregiver completed a brief questionnaire to ascertain whether there had been any major changes to the child's pre-existing educational or therapeutic intervention programmes (i.e. frequency, intensity, and duration of the interventions); none of the caregivers reported any changes in the services.

At the end of phase B(1), participants stopped listening to the TLP and returned to the clinic to complete phase A(2). The A(2) phase entailed four subsequent weekly observation sessions to assess the participant's response following the cessation of the intervention. To avoid bias, all observation sessions were video-recorded and separately coded by two raters (i.e. two graduate research assistants). The raters were also blinded to the session number and phase when watching the video sessions to prevent rater bias. During each session the primary investigator met with each caregiver to answer any questions and/or to exchange TLP CDs during the two B phases.

FINDINGS

Data were analysed using repeated measure graphs. The researchers were interested in determining the direction or slope of the trend lines of four or more data points, and the level of change among the first and last data points in each phase of the ABAB design, i.e. the A(1), B(1), A(2) and B(2) phases. Trend lines were individually calculated for each participant using data from the SPM HEA subtest, TOT overall score, SensOR positive behaviour summative score and SensOR negative behavioural summative score. Trend lines were calculated using the following formulas:

Slope
$$\alpha = n\Sigma(xy) - \Sigma x \Sigma yn / \Sigma x^2 - (\Sigma x)^2$$

Offset
$$\beta = \Sigma y - a\Sigma xn$$

Overall trend line formula
$$y = \alpha x + \beta$$

Although *Figures* 1–4 incorporate the trend lines of all three participants on every graph, each participant's response to the intervention will be reported individually for clarity.
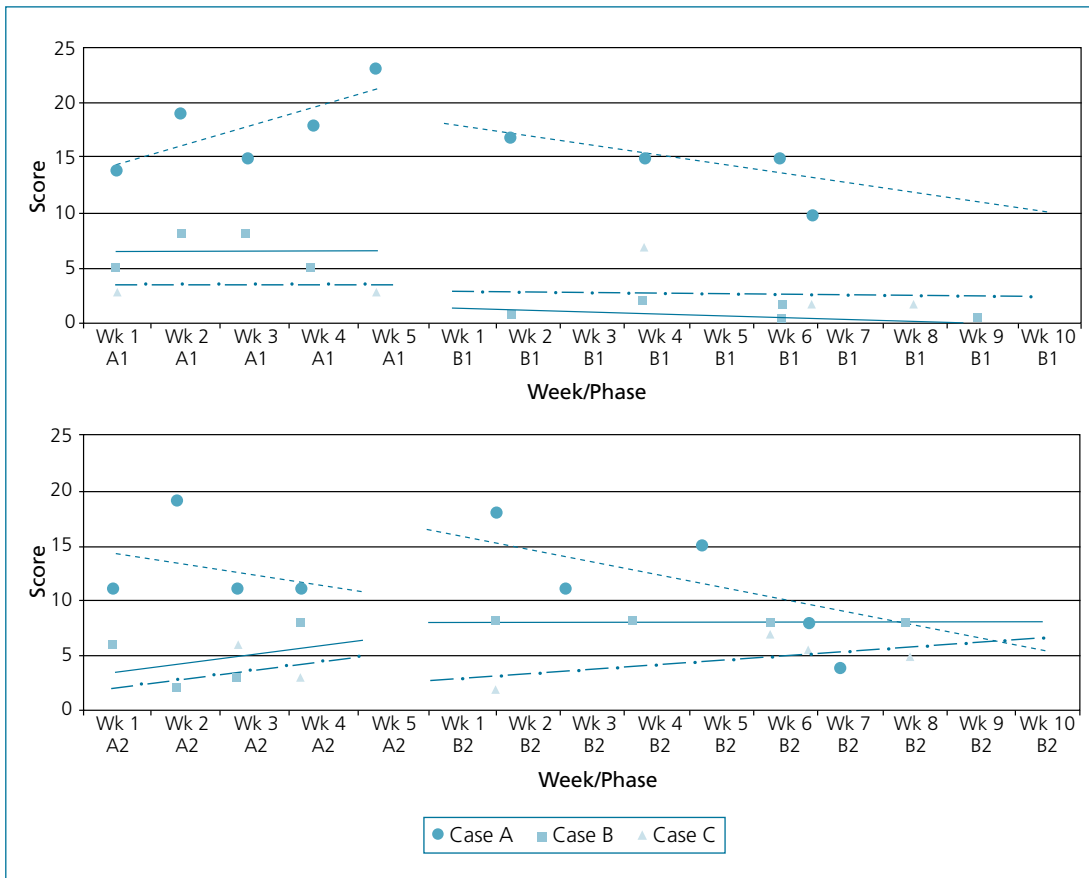
Figure 2. Sensory Over-Responsivity scales—negative behaviours

Sensory Over-Responsivity scales

Positive behaviours

Figure 1 shows the trend lines for the positive behaviours in the SenSOR scales for each of the three participants.

The trend line for Case A, which represents the frequency of the total number of positive behaviours in response to auditory stimuli from the A(1) phase of the SensOR scales, is downward sloping. This indicates a decreased frequency of positive behaviours in response to auditory stimuli. When the sensory-based intervention was introduced during the B(1) phase, the participant exhibited higher frequencies of positive behaviours than in phase A(1), as the upward trend line demonstrates. When the intervention was removed in phase A(2), the presence of positive behaviours dipped slightly in number and remained relatively flat. When the intervention was resumed in phase B(2), the subject's positive behaviour scores trended upward, with a higher frequency of positive behaviours. Thus, the participant demonstrated a greater frequency of positive behaviours during the intervention phases, indicating a greater level of acceptance of the stimuli.

The trend line for Case B, which represents the frequency of the total number of positive

behaviours in response to auditory stimuli from phase A(1) of the SensOR scales, remained relatively flat. When the intervention was introduced in the B(1) phase, the line trended upwards indicating a higher frequency of positive behaviours. When the intervention was discontinued during phase A(2), the trend line sloped downward. The trend line remained flat when the intervention was resumed in phase B(2).

The trend line for Case C in phase A(1) sloped downward, indicating a decreased frequency of positive behaviours, which demonstrates non-acceptance of the auditory stimuli. Early in phase B(1), the participant exhibited a higher frequency of positive behaviours than in A(1) but the trend line remained flat overall. In phase A(2), the scores trended downward, indicating a decreased frequency of positive behaviours toward the auditory stimuli. The participant continued to demonstrate a decrease in the frequency of positive behaviour even after the intervention was resumed in phase B(2).

Negative behaviours

Figure 2 shows the trend lines for the negative behaviours in the SenSOR scales for each of the three participants.
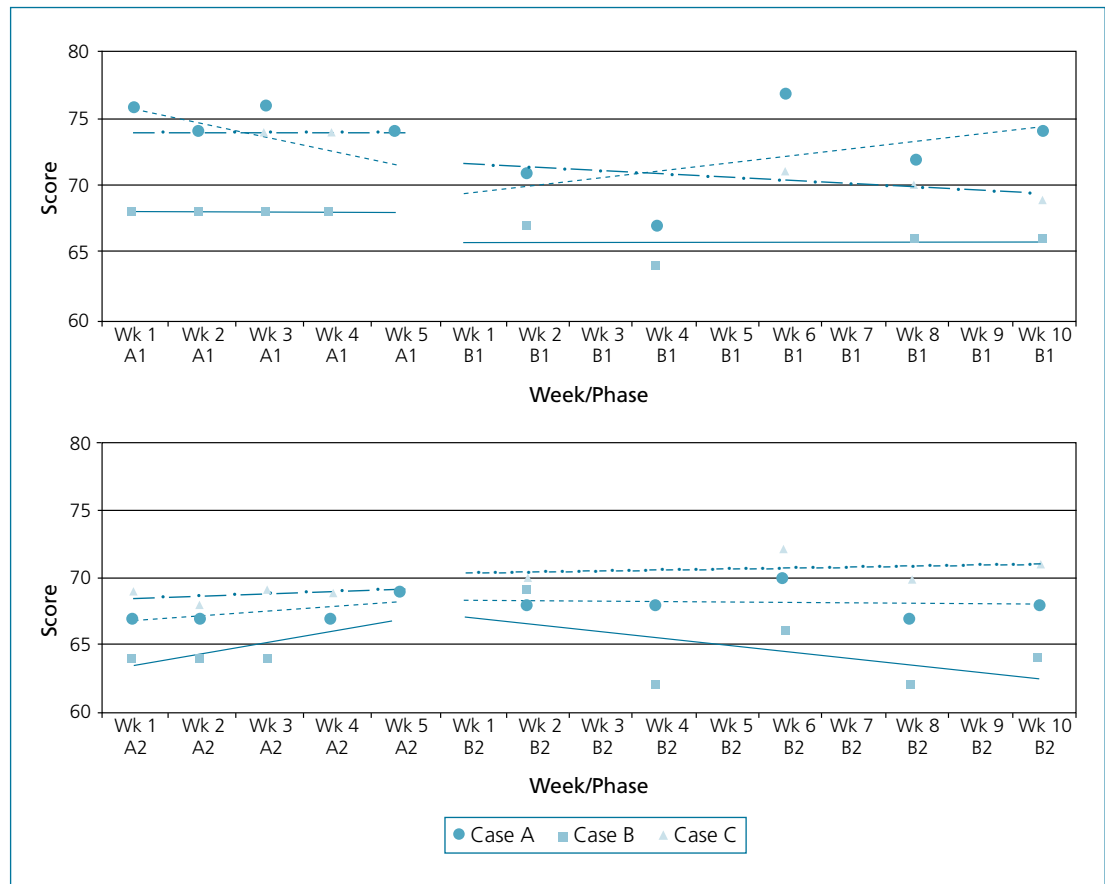
Figure 3. Sensory Processing Measure—auditory sensory processing subtest (HEA)

The trend line for Case A, which depicts the frequency of negative behaviours in response to auditory stimuli, is upward sloping, thus indicating a higher frequency of negative behaviours during phase A(1). With the implementation of the intervention, the trend line sloped downward, indicating a decrease in the frequency of negative behaviours exhibited. When the intervention was removed during phase A(2), the frequency of negative behaviours rose but the overall slope of the trend line was downward. When the intervention was resumed in phase B(2), the trend line continued to slope downward, indicating a reduced frequency of negative behaviours in response to the auditory stimuli.

The trend line for Case B in the A(1) phase is flat, indicating no change in the frequency of negative behaviours exhibited in response to auditory stimuli. When the intervention was initiated in phase B(1), the trend line sloped slightly downward, indicating a slight reduction in the frequency of negative behaviours. When the intervention was withheld in phase A(2), the trend line sloped upward, indicating a rise in the frequency of negative behaviours observed. The resumption of the intervention in phase B(2) did not result in any change; the trend line was flat.

The trend line for Case C in phase A(1) is relatively flat, which indicates no change over time in the frequency of negative behaviour in response to auditory stimuli. When the intervention was initiated in phase B(2), the trend line remained flat. During phase A(2), the frequency of negative behaviours exhibited by the participant did rise and the trend line sloped upward. When the intervention was resumed in B(2), the trend line remained stable indicating no change in the frequency of negative behaviours in response to the auditory stimuli.

Sensory Processing Measure
Auditory processing subtest

The *t* scores for caregivers' perceptions of their child's auditory sensory processing were tracked using the auditory domain (HEA subtest) on the SPM (*Figure 3*).

For Case A, during phase A(1), the caregiver reported a reduced frequency of behaviours that indicate difficulty in sensory processing; this is evidenced by the downward slope of the trend line. When the TLP intervention was introduced during phase B(1), the caregiver reported more difficulty with auditory sensory processing, as indicated by the rising trend line. When the
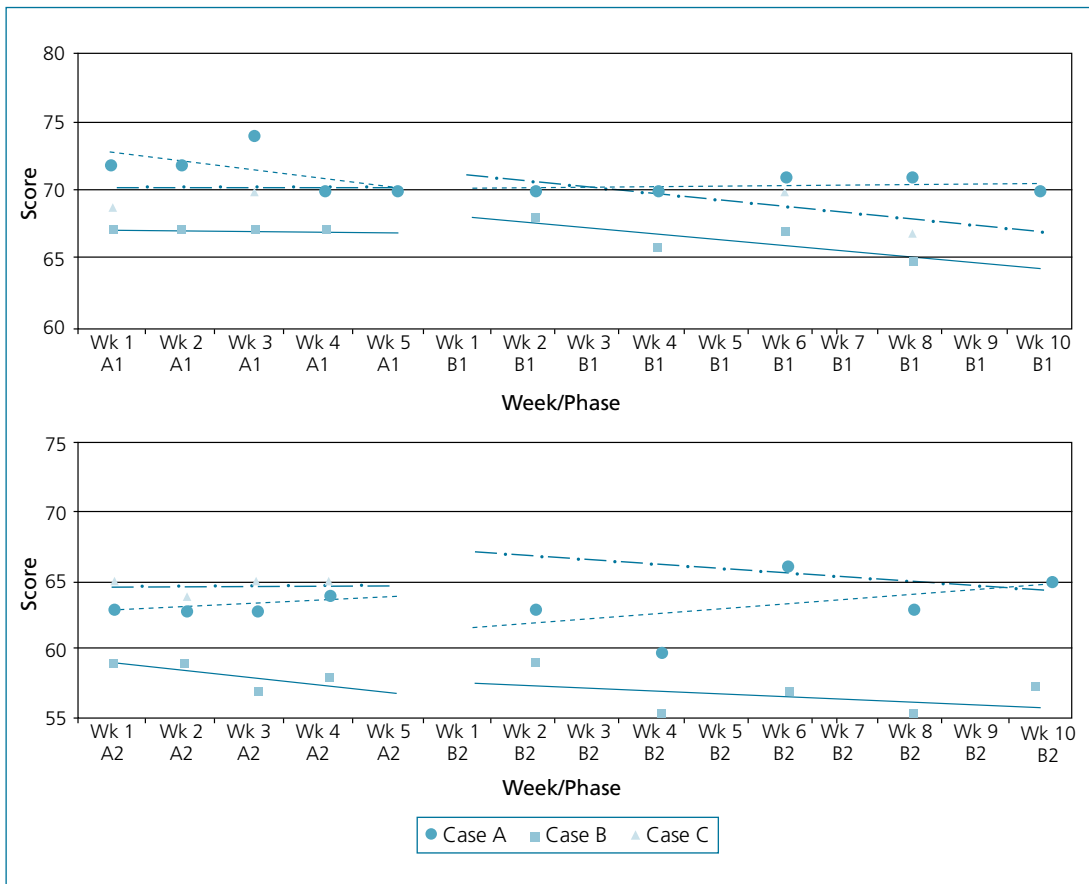
Figure 4. Sensory Processing Measure—total sensory processing score (TOT)

intervention was discontinued in phase A(2), the caregiver initially reported a reduced frequency of behaviours that indicate difficulty in sensory processing; however, over time the frequency of behaviours began to rise. When the intervention was resumed in B(2), the trend line remained flat, indicating that the caregiver saw no change in the participant's response to auditory stimuli.

For Case B, the caregiver did not report any changes in behaviours related to sensory processing in response to auditory stimuli in phase A(1); the trend line was flat. When the intervention was introduced in phase B(1), the caregiver initially reported a reduction in behaviours that indicate difficulty with auditory sensory processing; this trend remained stable throughout phase B(1). When the intervention was stopped, the caregiver reported a steady rise in frequency of behaviours indicating difficulty with auditory sensory processing. When the intervention was resumed in phase B(2), the caregiver reported a steady decrease in the frequency of these behaviours over time, again indicating that the caregiver perceived that the participant was exhibiting less difficulty processing auditory stimuli.

For Case C, the trend line was flat, indicating stable HEA scores during phase A(1).

When the intervention was introduced during phase B(1), the caregiver reported a reduced frequency of behaviours indicative of auditory processing difficulty, with a gradual reduction in behaviours over time; this is indicated by the downward sloping trend line. When the intervention was discontinued in phase A(2), the caregiver noted no change in behaviours, resulting in a flat trend line over the course of the phase. When the intervention resumed, the trend line remained unchanged, indicating no further change in the participant's behaviour as perceived by the caregiver.

Total sensory processing

The t scores for caregivers' perceptions of their child's overall sensory processing were tracked using their TOT scores on the SPM (*Figure 4*). The TOT scores included subtotals from other sensory processing domains, e.g. tactile and vestibular processing.

For Case A, during phase A(1), the caregiver reported a reduction in the frequency of behaviours that indicate sensory processing dysfunction, as evidenced by the downward sloping trend line. During phase B(1), the caregiver reported a slight rise in the frequency

of behaviours towards the end of the phase, resulting in a slight rise in the trend line. When the intervention was discontinued in phase A(2), the trend line shows a slight rise, indicating that the caregiver perceived the child to demonstrate great difficulty with sensory processing. The caregiver continued to report an increase in such behaviours, resulting in increased TOT scores during phase B(2).

The caregiver's TOT scores for Case B were stable during the A(1) phase. When the intervention was introduced in phase B(1), the caregiver perceived a reduced frequency of behaviours exhibited by the participant. These scores continued to decrease during phase A(2). The caregiver reported an initial increase in the frequency score when the participant resumed the intervention in phase B(2), but the scores then began to decrease again over time.

The caregiver's TOT scores for Case C during phase A(1) resulted in a slightly rising trend line. When the intervention was introduced during phase B(2), the caregiver reported lower TOT scores over time, resulting in a trend line that sloped downward. When the intervention was discontinued, the caregiver reported a slightly higher TOT score that remained relatively stable during phase A(2). When the intervention resumed in B(2), the trend line of TOT scores sloped downward, indicating that the caregiver perceived a slight decrease in the frequency of behaviours indicative of sensory processing difficulties.

DISCUSSION

This study's purpose was to determine whether TLP, a 20-week, sound-based auditory stimulation method, reduced SOR to auditory stimuli in three children who had been diagnosed with ASD. The results of this case series unveil several implications that may inform the use of sound-based interventions as a part of routine occupational therapy treatment for children with ASD and sensory processing difficulties.

Each participant responded differently to TLP during the 28 weeks but demonstrated an improved behavioural response as a result of the intervention during at least one phase of the study. Each caregiver interpreted their child's progress with auditory sensory processing (HEA) and overall sensory processing (TOT) differently. Case A demonstrated the most significant improvement in reduced auditory SOR on the examiner-based assessment (SensOR scales) compared with Cases B and C. However, Case A's caregiver did not perceive similar

improvements in the child's behaviours as measured through the caregiver questionnaire (SPM). Conversely, Case B's scores on the SensOR scales indicated a minimal impact of TLP with the lessening of auditory SOR, yet the participant's caregiver subjectively reported improvements in both auditory SOR and overall sensory processing on the SPM. Finally, Case C appeared to be positively impacted at least temporarily by the TLP intervention during phase B(1), with fewer negative behaviours during phase B(1) based on the SensOR scores. On the SPM, Case C's caregiver perceived an improvement in performance in auditory sensory processing.

While the results of this study are mixed, the positive trends that emerged from each case provide evidence that TLP may be a valuable intervention for children with ASD and auditory sensory processing difficulties. Improvements in auditory sensory processing were found across the differing phases of the study, both when the intervention was implemented (phases B(1) and B(2)) and withdrawn (phase A(2)). However, this improvement was variable and should be viewed with caution.

The manufacturers of TLP, Advanced Brain Technologies, suggest their intervention may improve functions such as sensory processing, academic functioning, behavioural organisation and motor skills. However, there continues to be weak evidence in the literature to support this. Therefore, it is important for clinicians planning to use or who are currently using sound-based interventions to:

■ Clearly understand sensory processing and sensory modulation disorders
■ Generate a specific hypothesis for implementing TLP or other sound-based interventions
■ Use reliable and valid measures to track clients' functional outcomes at home, school and in the community. Functional measures should include goal attainment scaling, contextual caregiver assessments (including the SPM school form) and standardised norm-referenced assessments (e.g. Miller Function and Participation Scales).

In this study, Case A demonstrated the most severe auditory SOR. This may have allowed the SensOR scales to capture what could be considered the largest improvement among the three cases. Case B demonstrated the most limited SOR improvement that the SensOR scales were able to measure, while Case A demonstrated the most room for improvement based on pre-testing scores compared with Cases B and C. These findings lend some support to previous research studies exploring the effectiveness of TLP. Previous

studies into the efficacy of TLP (Nwora and Gee, 2009; Francis, 2011; Gee et al, 2013) also reported improved sensory responsivity to contextual sensations, especially auditory and sound-based interventions (Hall and Case-Smith, 2007; Bazyk et al, 2010).

ASD is a complex condition that presents with and without sensory processing difficulties (American Psychiatric Association, 2013). As children with ASD have varying degrees of SOR, they will respond differently to interventions, and outcomes may be more favorable for those who have more intense symptomology of over- or under-responsivity. Other research supports a similar conclusion. For example, Bagatell et al (2010) reported that children with ASD responded differently to the implementation of therapy ball chairs in the classroom. The children who responded positively to the therapy ball chair were those who demonstrated more severe impairments with sensory modulation disorder in vestibular processing. Practitioners should take a more judicious approach when implementing sound-based interventions by aligning the impact of the sensory processing deficit and the purpose of the intervention. This process may assist practitioners with identifying possible relationships between the intervention and a measurable functional outcome.

On a broader scale, the results of this study may encourage therapy and educational professionals to align clients' particular sensory processing characteristics with a specific sensory-based or sensory motor intervention. This process is necessary for generating more positive and reliable outcomes with sensory-related interventions for children with ASD and sensory processing disturbances.

Limitations

This study has several methodological limitations. First, due to time constraints, the researchers were unable to obtain consistent baseline data during the A(1) phase. Such consistent baseline data might have demonstrated trend lines that were flat or trending in a direction indicating an increase in negative behaviours resulting from auditory stimuli in the assessment measures.

Second, the sample size comprised only three particpants and lacked homogeneity with regard to the severity of ASD and auditory SOR. The duration of the study and the demands placed upon the caregivers may have influenced caregivers' perceptions of the effectiveness of the intervention. While the manufacturer of TLP recommends 20 weeks of continuous intervention, this study divided the intervention into two phases, with a four-week break between the two B phases. Thus, the design, while quasi-experimental in nature, does not enable generalisation to the broader population as a result of internal and external validity issues inherent with the repeated measures used in this case series.

Finally, the study did not include a differential diagnosis of auditory SOR and phonophobia.

CONCLUSIONS

Paediatric therapeutic and educational professionals use a wide variety of sensory-based adjunctive interventions for children with ASD and sensory processing difficulties. TLP is one of several sound-based interventions for children on the autism spectrum who also experience auditory sensory processing difficulties. While the results are mixed, the positive trends that emerged from each case provide evidence that TLP may be a valuable intervention for children with ASD and auditory sensory processing difficulties. Additional and more rigorous research must be conducted into using TLP for individuals with ASD. Therapists must also continue to scrutinise such interventions and their appropriateness given factors such as the best available evidence, client factors, contextual elements and financial resources. **IJTR**

Advanced Brain Technologies (ABT) (2014) *The Listening Program*. www.thelisteningprogram.com (accessed 18 December 2014)

American Psychiatric Association (2013) *Diagnostic and Statistical Manual of Mental Disorders*. 5th edn. American Psychiatric Association, Arlington, Virginia

Bagatell N, Mirigliani G, Patterson C, Reyes Y, Test L (2010) Effectiveness of therapy ball chairs on classroom participation in children with autism spectrum disorders. *Am J Occup Ther* **64**(6): 895–903. doi: 10.5014/ajot.2010.09149

Baguley D (2003) Hyperacusis. *J Royal Soc Med* **96**(12): 582–5

Baranek G (2006) Efficacy of sensory and motor interventions for children with autism. *J Autism Dev Disord* **32**(5): 397–422. doi: 10.1023/A:1020541906063

Baranek GT, David FJ, Poe MD, Stone WL, Watson LR (2006) Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *J Child Psychol Psychiatr* **47**(6): 591–601. doi: 10.1111/j.1469-7610.2005.01546.x

Bazyk S, Cimino J, Hayes K, Goodman G, Farrell P (2010) The use of therapeutic listening with preschoolers with developmental disabilities: A look at the outcomes. *J Occup Ther, Schools, Early Interv* **3**(2): 124–38. doi: 10.1080/19411243.2010.491013

Bettison S (1996) The long-term effects of auditory training on children with autism. *J Autism Dev Disord* **26**(3): 361–73. doi: 10.1007/BF02172480

Case-Smith J, Arbesman M (2008) Evidence-based review of interventions for autism used in or of relevance to occupational therapy. *Am J Occup Ther* **62**(4): 416–29

Francis H (2011) Effects of 'The Listening Program' on children with profound and multiple learning difficulties. *Int J Ther Rehabil* **18**(11): 611–21. doi: 10.12968/ijtr.2011.18.11.611

Gee BM, Devine N, Werth A, Phan V (2013) Paediatric occupational therapists' use of sound-based interventions: A survey study. *Occup Ther Int* **20**(3): 155–62. doi: 10.1002/oti.1354

Gee B, Thompson K, St. John H (2014) Efficacy of a sound-based intervention with a child with an autism spectrum disorder and auditory sensory over-responsivity. *Occup Ther Int* **21**(1): 12–20. doi: 10.1002/oti.1359

Greenspan S, Weider S (1997) Developmental pattens and oucomes in infants and children with disorders relating and communicating: A chart review of 200 cases of children with autisic spectrum diagnoses. *J Dev Learning Disord* **1**: 87–142

Hall L, Case-Smith J (2007) The effect of sound-based intervention on children with sensory processing disorders and visual-motor delays. *Am J Occup Ther* **61**(2): 209–15. doi: 10.5014/ajot.61.2.209

Hitoglou M, Ververi A, Antoniadis A, Zafeiriou DI (2010) Childhood autism and auditory system abnormalities. *Pediatr Neurol* **42**(5): 309–14. doi: 10.1016/j.pediatrneurol.2009.10.009

Kern JK, Trivedi MH, Garver CR et al (2006) The pattern of sensory processing abnormalities in autism. *Autism* **10**(5): 480–94

Klein AJ, Armstrong BL, Greer MK, Brown FR (1990) Hyperacusis and otitis media in individuals with Williams's syndrome. *J Speech Hear Disord* **55**(2): 339–44. doi: 10.1044/jshd.5502.339

Koegel R, Openden D, Koegel L (2004) A systematic desensitization paradigm to treat hypersensitivity to auditory stimuli in children with autism in family contexts. *Res Prac Persons Severe Disabil* **29**(2): 122–34. doi: 10.2511/rpsd.29.2.122

Miller LJ (2006) *Sensational Kids: Hope and Help for Children with Sensory Processing Disorder*. GP Putnam's Sons, New York

Miller LJ, Coll J, Schoen S (2007a) A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *Am J Occup Ther* **61**(2): 228–38. doi:10.5014/ajot.61.2.228

Miller LJ, Anzalone M, Lane S, Chermak S, Osten E (2007) Concept evolution in sensory integration: A proposed nosology for diagnosis. *Am J Occup Ther* **61**(2): 135–40. doi:10.5014/ajot.61.2.135

Nwora A, Gee B (2009) A case study of a five-year-old child with pervasive developmental disorder-not otherwise specified using sound-based interventions. *Occup Ther Int* **16**(1): 25–43. doi: 10.1002/oti.263

Parham D, Ecker C, Miller-Kuhananeck H, Henry D, Glennon T (2007a) *Sensory Processing Measure (SPM) manual*. Western Psychological Services, Los Angeles

Parham D, Cohn E, Spitzer S, Koomar J, Miller L, Burke J et al (2007b) Fidelity in sensory integration intervention research. *Am J Occup Ther* **61**: 216–27. doi: 10.5014/ajot.61.2.216

Portney L, Watkins W (2009) *Foundations of Clinical Research: Applications for Practice*. 3rd edn. Pretence Hall, Upsaddle River, New Jersey

Prizant BM, Wetherby AM, Rydell PJ (2000) Communication intervention issues for children with autism spectrum disorders. In: Wetherby AM, Prizant BM, eds. *Autism Spectrum Disorders: A Transactional Developmental Perspective*. Brookes, Baltimore: 193–224

Prizant BM, Wetherby AM, Rubin E, Laurent A (2003) The SCERTS Model: A transactional, family-centered approach to enhancing communication and socioemotional abilities of children with autism spectrum disorder. *Infants Young Child* **16**(4): 296–316

Schoen SA, Miller LJ, Green KE (2008) Pilot study of the Sensory Over-Responsivity Scales: assessment and inventory. *Am J Occup Ther* **62**(4): 393–406

Stiegler LN, Davis R (2010) Understanding sound sensitivity in individuals with autism spectrum disorders. *Focus Autism Other Dev Disabl* **25**(2): 67–75. doi: 10.1177/1088357610364530

Stewart K (2010) Purposes, processes and methods of evaluation. In: *Occupational Therapy For Children*. 6th edn. Case-Smith J, O'Brien J, eds. Elsevier, Missouri: 193–215

Tomchek SD, Dunn W (2007) Sensory processing in children with and without autism: a comparative study using the short sensory profile. *Am J Occup Ther* **61**(2): 190–200. doi: 10.5014/ajot.61.2.190

Thabet EM, Zaghloul HS (2013) Auditory profile and high resolution CT scan in autism spectrum disorders children with auditory hypersensitivity. *Eur Arch Otorhinolaryngol* **270**(8): 2353–8. doi: 10.1007/s00405-013-2482-4

Tharpe AM, Bess FH, Sladen DP, Schissel H, Couch S, Schery T (2006) Auditory characteristics of children with autism. *Ear Hear* **27**(4): 430–41. doi: 10.1097/01.aud.0000224981.60575.d8