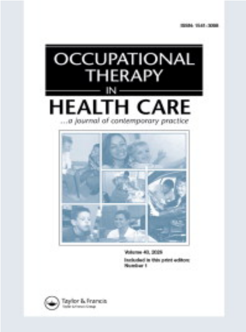

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ABSTRACT

Many children with autism spectrum disorder (ASD) have altered sensory processing – including auditory sensory over-responsivity (SOR). Few treatment options exist for children with ASD and auditory SOR. This study investigated whether music-based auditory stimulation (The Listening Program® SPECTRUM with Waves™ bone conduction headphones), could reduce auditory SOR, sensory dysfunction, and behaviors common to children with ASD and improve adaptive functioning. Six boys between the ages of 5 and 10 with ASD and auditory SOR completed listening sessions at home for 40 wk. Participants had statistically significant improvements in the Hearing construct of the Sensory Processing Measure that were sustained 3 months post-intervention. Participants also had significant improvements across multiple other sensory constructs, social skills, and communication skills. This study provides support for The Listening Program® SPECTRUM with Waves™ bone conduction headphones to improve sensory processing and reduce hypersensitivity to sound, which may lead to better social and communication skills for children with ASD and auditory SOR. Larger, randomized-controlled studies are needed.

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autism spectrum disorder; auditory sensory-over responsivity; sensory processing disorder; hypersensitivity to sound; music-based auditory stimulation; The Listening Program®

Introduction

Autism spectrum disorder (ASD) is common. Among 8 year-old children, 1 in 31 have ASD (CDC, 2025). In addition to deficits in social communication and restricted/repetitive patterns of behavior, many children with ASD present with hyper- or hyporeactivity to sensory input (APA, 2013; CDC, 2025). One of the most common sensory differences in children with ASD is hypersensitivity to sound—also referred to as auditory sensory over-responsivity (SOR) (Gomes et al., 2008; Gonçalves & Monteiro, 2023). Auditory SOR is a broad term used to describe symptoms such as increased perception and decreased tolerance of sounds, and may be related to

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differences in auditory processing seen among children with ASD (Danesh et al., 2021; Gonçalves & Monteiro, 2023; Marco et al., 2011; Ocak et al., 2018; Poulsen et al., 2024; Remington & Fairnie, 2017; Schwartz et al., 2018).

Children with ASD and auditory SOR can have negative emotional reactions to a variety of sounds in their environment—especially loud, sudden, and high-pitched sounds (Poulsen et al., 2024; Scheerer et al., 2022; Williams et al., 2021). These reactions can lead to behavior problems and decreased adaptive life skills. Many children with ASD have increased auditory perception, decreased ability to filter irrelevant noises, decreased habituation to sound, and may experience "sensory overload" when encountering auditory input (Danesh et al., 2021; Gonçalves & Monteiro, 2023; Marco et al., 2011; Ocak et al., 2018; Poulsen et al., 2024; Remington & Fairnie, 2017; Schwartz et al., 2018). This "overload" can lead to intense feelings of distress or panic; some people with ASD report feeling a loss of volitional control over their behavior (Poulsen et al., 2024).

For example, some children may have aversive reactions to the flush of a toilet and subsequently avoid using the toilet. Other children may experience an acute stress response when they hear certain sounds which can lead to crying, tantrums, or even aggressive behavior such as hitting or biting. From a study investigating family experiences of decreased sound tolerance, one parent reported: "Sounds are so painful that it feels like he is being attacked or hurt. He gets very angry" (Scheerer et al., 2022). Another parent, when describing her child, reported: "He says that he can't think and he feels detached from his body. He also says that his body takes over and he can't stop his reactions" (Scheerer et al., 2022).

If children with ASD and auditory SOR perceive auditory information as unpleasant, noxious, and distressing, they will likely avoid auditory input. Avoidance can limit opportunities to develop social, cognitive, and language skills related to accepting auditory information from the world (Marco et al., 2011). Sounds are part of daily life, and difficulty tolerating sounds can significantly impact participation in activities of daily living. Despite the increased prevalence of ASD (CDC, 2025) and associated auditory SOR among children with ASD, along with the potential impact of auditory SOR on behavior, few treatment options exist. Among the limited available options, interventions fall broadly into the following categories: exposure therapy, sensory integration therapy, cognitive behavioral therapy, compensatory/avoidance strategies, and sound-based intervention.

Sound-based intervention, including music-based auditory stimulation, is a promising option to treat auditory SOR in children with ASD. Two recent review articles investigated the existing evidence for sound-based interventions with children with ASD and/or sensory processing disorder and concluded that sound-based interventions may improve behavioral responses in these populations (Shahrudin et al., 2022, Simhon et al., 2019). In particular, Simhon et al. (2019) found a relationship between the use of music-based auditory stimulation and improvements in sensory processing. However, neither review was able to make strong conclusions due to small sample sizes, unverified methodology, absence or lack of a control group, and/or insufficient follow up in the studies included.

Two small studies investigated the effects of specific music-based auditory stimulation programs on children with sensory processing impairments or ASD and auditory SOR (Gee et al., 2015; Schoen et al., 2015). One study found that 40 h of the Integrated Listening Systems Focus Series over an 8-week period led to improvement in home and education-related goals for all seven participants. It also led to changes in arousal level, as measured by parent report and the Sensory Challenge Protocol, for five participants (Schoen et al., 2015). The other study found that 50 h of The Listening Program® over two 10-week periods led to an improved behavioral response during at least one study phase for all three participants, though responses were highly variable (Gee et al., 2015). Notably, in both of these studies, music was modified to provide gradual exposure to higher frequency sounds and participants used bone conduction headphones, so auditory stimuli was simultaneously transmitted *via* both air and bone conduction. Children with ASD typically find higher frequency—and subsequently higher pitch—sounds more distressing (Scheerer et al., 2022), so these interventions use a graded approach to build tolerance to higher frequencies. Bone conduction headphones are thought to reduce the acute stress ("fight or flight") response that children with auditory SOR may experience with sound (Lucker & Doman, 2019).

Uncertainty continues to exist for occupational therapists and families of children with ASD and auditory SOR on what intervention(s) to choose. Many occupational therapists recommend sound-based interventions based on the limited available evidence, clinical experience, and/or expert opinion due to a need to treat a growing number of children with ASD and auditory SOR (Gee et al., 2013). The Listening Program® SPECTRUM with Waves™ bone conduction headphones is a type of music-based auditory stimulation specifically designed for people with auditory hypersensitivity and sensory processing challenges. It uses a modular session structure with a gradual warm-up phase, targeted stimulation phase, and a regulated cool-down phase to reduce the likelihood of overstimulation. Compared to other music-based auditory stimulation programs (including those previously studied), it uses a longer duration with higher total dosage to gradually improve tolerance to sound. The manufacturer recommends SPECTRUM users complete 30 min of listening 5 days per week for 40 wk (100 h total). Other programs are implemented more quickly, over 8—20 wk, with approximately half the total listening time; this may be challenging and less effective for those with heightened auditory defensiveness or significant difficulty habituating to sound.

The purpose of this study was to collect pilot data to explore if the SPECTRUM program could lead to less sensory dysfunction—including reduction in auditory SOR—for the target population. The second purpose of this study was to identify if use of the SPECTRUM program could also lead to changes in behaviors common to children with ASD and overall adaptive functioning. The third purpose of this study was to evaluate if changes in sensory, behavior, and/or function could be maintained post-intervention, which could suggest neuroplastic changes in the systems contributing to hypersensitivity to sound.

Materials and methods

Participants

Eight children with ASD and auditory SOR participated in this study. To be included in the study, children needed to: (1) be between 5 and 10 years-old, (2) have a diagnosis of ASD, (3) have auditory SOR (as defined by scoring "Some Problems" or "Definite Dysfunction" on the Hearing construct of the Sensory Processing Measure), and (4) have a caregiver available to supervise listening sessions at home. Children were excluded from the study if they: (1) had a seizure disorder, hearing impairments, cerebral palsy, Fragile X syndrome or genetic disease, (2) did not speak English, or (3) had previously used a similar listening program, sound-based intervention, or music-based auditory stimulation.

Materials

The Listening Program® SPECTRUM with Waves™ headphones

Developed by Advanced Brain Technologies, The Listening Program® is music listening therapy intended to promote optimal brain health and includes a variety of programs for children and adults with or without health conditions. Per the manufacturer, the SPECTRUM program uses gentle and gradual sound stimulation across low, mid-low, mid-high, and high frequency zones. SPECTRUM follows a low-to-high frequency progression while also incorporating a cross-training approach. Within a given listening session, the program modules alternate between frequency zones to help the brain develop flexibility and tolerance for a wider range of sound. Waves™ headphones provide auditory input through the ears *via* air conduction; they also provide bone conduction *via* a conductor in the headband that provides gentle vibrations at the top of the skull during listening (Advanced Brain Technologies, 2013n.d.).

Measures

This study used 4 standardized, questionnaire-based outcome measures completed by participants' parents. The study team selected this array of outcome measures based on reliability, validity, availability, use in pediatric occupational therapy research, and focus on functional skills—both with and without normative data—to gain a broad understanding of the effects of the SPECTRUM program on our target population. Parent-report measures were selected because parents implemented the intervention at home and were able to provide feedback on their children's functional skills during daily routines.

Adaptive Behavior Assessment System, Third Edition (ABAS-3)

The ABAS-3 is a widely used, reliable, norm-referenced tool that measures adaptive functioning across the lifespan, using three domains: Conceptual, Social, and Practical (Harrison & Oakland, 2015). A General Adaptive Composite (GAC) can be derived from these three domains to provide an overall measure of adaptive behavior. The ABAS-3 can be completed by parents, teachers, or self-report (for people ≥16 years-old). In this study, parents completed the assessment using the Parent Form. Parents rated if their child performed a behavior or skill on a scale from 0 (not able) to 3 (always) for each item. Higher ABAS-3 scores represent better adaptive functioning.

Sensory Processing Measure (SPM)

The SPM is a well-known, reliable, valid, norm-referenced tool that measures sensory integration and sensory processing for children 5 to 12 years-old across eight constructs: Social Participation, Vision, Hearing, Touch, Body Awareness, Balance and Motion, Planning and Ideas, and Total Sensory Systems (Brown et al., 2010; Dugas et al., 2018; Parham et al., 2007). The SPM can be completed by parents, teachers and/or school staff, or self-report (for people ≥12 years-old). In this study, parents completed the Home Form to rate how often their child exhibits specific behaviors using a scale from 1 (never) to 4 (always). Lower scores on the SPM represent improvement (or lessened sensory dysfunction).

Pediatric Evaluation of Disability Inventory Computer Adaptive Test for autism spectrum disorders (PEDI-CAT [ASD])

The PEDI-CAT is a reliable and valid tool that measures functional abilities for children and youth with a variety of physical and/or behavioral conditions, using three domains: Daily Activities, Mobility, and Social/Cognitive (Haley et al., 2012; Kramer et al., 2016). A fourth domain, Responsibility, measures the extent to which the caregiver or child takes responsibility for managing life tasks. The PEDI-CAT (ASD) is a version of the PEDI-CAT adapted for use with children and youth with ASD. Given the unique characteristics of children with ASD, this module includes additional directions to help parents select an appropriate rating, new or revised items in some domains, and adjusted scaling of some items in the Social/Cognitive domain. The PEDI-CAT can be completed by the child's parent (or primary caregiver) or the child's therapist/clinician. For this study, parents completed the Daily Activities and Social/Cognitive domains within the ASD module. For these domains, parents rated their child's typical performance for each skill using the following scale: unable, hard, a little hard, or easy. Higher scores represent higher levels of function.

Autism Treatment Evaluation Checklist (ATEC)

The ATEC was developed by two ASD researchers to measure treatment effectiveness. (Rimland & Edelson, 1999), and research supports the reliability and validity of this tool (Freire et al., 2018; Magiati et al., 2011; Rimland & Edelson, 1999). The ATEC measures changes in ASD symptoms over time using four subscales: Speech/Language/Communication, Sociability, Sensory/Cognitive Awareness, and Health/Physical Behavior. The four subscale scores can be used to calculate a total score. The ATEC can be completed by parents, teachers, or caretakers. For this study, parents completed the assessment. For the Speech/Language/Communication subscale, parents rated each phrase for their child using the following scale: not true, somewhat true, or very true. For the Sociability and Sensory/Cognitive Awareness subscales, they rated each phrase as: not descriptive, somewhat descriptive, or very descriptive. For the Health/Physical/Behavior subscale they rated each phrase as: not a problem, minor problem, moderate problem, or serious problem. Lower scores on the ATEC represent improvement (or fewer problems).

Procedures

Children with ASD and auditory SOR ages 5—10 were recruited for this study. Most children were recruited from a large pediatric hospital system. Flyers were posted at the system's outpatient rehabilitation and therapy clinics. Healthcare providers also gave flyers to parents of children who met the inclusion criteria and were interested in the study. This study was registered in ClinicalTrials.gov; some parents learned about the study from ClinicalTrials.gov and reached out to the study team to inquire about participation in the study.

The Principal Investigator (PI)—an occupational therapist with 25+ years of experience treating children with ASD—screened each child for eligibility and answered any questions *via* phone call with the child's parent. If children were eligible and parents confirmed interest in participating, an in-person meeting at an outpatient clinic was scheduled. During this meeting (Visit 1), the PI thoroughly reviewed the study and obtained informed consent. Parents completed 4 questionnaire-based assessments—ABAS-3, PEDI-CAT (ASD), SPM, and ATEC—about their child. The PI completed an in-depth education session with each family, including key points about auditory SOR and how to use The Listening Program® SPECTRUM with Waves™ headphones. Families were given a choice between (1) a base schedule of two 15-minute sessions with at least 30 min in between sessions of listening per day for 5 consecutive days and 2 days off or (2) a condensed schedule of one 30-minute session of listening per day for 5 consecutive days and 2 days off.

Each family left Visit 1 with The Listening Program® SPECTRUM with Waves™ headphones and a handout with their selected listening schedule. Families completed the program as instructed within the home environment for 40 wk. The 4 questionnaire-based assessments were re-administered at the 41st week after treatment (Visit 2), and then again after 3 months of no treatment (Visit 3); visits were completed in-person at an outpatient clinic or using a hospital-approved virtual platform.

Between testing sessions for both groups, parents and investigators set up 3 phone calls or meetings *via* hospital-approved virtual platform at approximately 10-week intervals to check in and answer questions. The total time spent face-to-face with the PI was 2.5 - 5 h per participant.

Statistical methods

Statistical analysis was completed by the hospital system's lead biostatistician. Analysis was exploratory and intended to identify clinically meaningful signals. Continuous variables were presented as means and standard deviations. Categorical variables were presented as frequencies and proportions. The Paired t-test was used to test difference in means between different visits. The statistical analyses were performed with SAS software, version 9.4. This study was reviewed and approved by the University of Texas Southwestern Medical Center Institutional Review Board, #STU-2019-1698.

Results

All eight participants were male. See Table 1 for more detailed demographics. Participant 1 did not return after Visit 1, and Participant 3 did not follow study protocol. Data from the remaining six participants was included in the analysis.

Table 1. Demographics.

Participant	Age	Sex	Current therapies	Current therapy settings	Previous therapies	Previous therapy settings
1*	5 years	Male	OT, ST	Outpatient, School	OT, PT, ST, Feeding	Home health, Outpatient, School, ECI
2	10 years	Male	OT, ST	School	OT, ST, Behavior	School
3*	9 years	Male	Feeding, behavior	Outpatient	PT	Outpatient
4	9 years	Male	None	n/a	OT, Behavior	Outpatient
5	6 years	Male	OT, ST	Outpatient	OT, ST, Feeding	Outpatient
6	9 years	Male	OT, ST	Outpatient, School	OT, PT, ST, Behavior	Home health, Outpatient, School
7	6 years	Male	None	n/a	OT, PT	Outpatient
8	5 years	Male	Behavior	Outpatient	OT, PT, ST	Outpatient

*Excluded from data analysis due to incomplete data or lack of adherence to study protocol

Table 2. ABAS-3 results.

Skill Area	Raw Score Visit 1 Scaled Score Visit 1	Raw Score Visit 2 Scaled Score Visit 2	Raw Score Visit 3 Scaled Score Visit 3	Raw Score P-value (Visit 2 vs. Visit 1) Scaled Score P-value (Visit 2 vs. Visit 1)	Raw Score P-value (Visit 3 vs. Visit 1) Scaled Score P-value (Visit 3 vs. Visit 1)
Communication	36.50 (17.54)	41.67 (6.91)	39.50 (10.62)	0.127	0.520
	4.33 (3.83)	5.50 (0.98)	5.16 (1.33)	0.034*	0.185
Community Use	13.67 (13.41)	14.00 (9.71)	14.17 (11.66)	0.936	0.920
	6.67 (3.56)	6.17 (2.35)	6.34 (3.20)	0.624	0.809
Functional Academics	22.50 (17.73)	24.50 (7.38)	24.83 (10.01)	0.536	0.593
	5.67 (4.27)	5.84 (1.72)	5.84 (2.14)	0.822	0.856
Home Living	23.00 (10.81)	29.33 (12.37)	28.50 (17.34)	0.265	0.472
	5.33 (2.34)	6.33 (2.83)	6.00 (3.98)	0.426	0.700
Health	29.17 (13.42)	31.84 (7.69)	34.00 (8.73)	0.434	0.233
	5.83 (3.92)	5.66 (2.48)	6.33 (2.17)	0.876	0.597
Leisure	28.50 (14.38)	31.00 (6.95)	30.50 (9.78)	0.419	0.638
	5.50 (3.08)	5.83 (2.34)	6.00 (3.02)	0.741	0.702
Self-Care	41.17 (14.92)	44.84 (7.89)	44.00 (11.23)	0.310	0.564
	5.50 (2.81)	5.00 (1.38)	5.33 (2.64)	0.415	0.883
Self-Direction	19.50 (15.36)	24.17 (10.58)	27.33 (15.42)	0.329	0.269
	4.83 (3.06)	4.83 (2.28)	5.83 (3.46)	1.000	0.511
Social	32.83 (19.20)	34.16 (12.29)	36.83 (12.74)	0.801	0.476
	4.17 (2.71)	4.17 (2.19)	4.84 (2.94)	1.000	0.603

Mean (standard deviation), * = statistically significant, α = 0.05

Domain	Standard Score Visit 1	Standard Score Visit 2	Standard Score Visit 3	Standard Score P-value (Visit 2 vs. Visit 1)	Standard Score P-value (Visit 3 vs. Visit 1)
Conceptual	70.83 (20.25)	73.50 (8.29)	74.66 (13.29)	0.466	0.511
Social	72.67 (15.34)	73.00 (10.65)	76.00 (17.44)	0.942	0.659
Practical	74.83 (16.61)	75.00 (12.12)	76.33 (16.80)	0.974	0.836
GAC	71.00 (17.89)	72.00 (10.83)	73.83 (16.73)	0.830	0.695

Mean (standard deviation), * = statistically significant, α = 0.05

ABAS-3 GAC scores increased between Visit 1 and Visit 2, and scores increased across all three domains as well. However, none of these changes were statistically significant. Similarly, GAC and all domain scores increased between Visit 1 and Visit 3, but no changes were statistically significant. One skill area within the Conceptual domain (Communication) had statistically significant improvement between Visit 1 and Visit 2. See Table 2 for ABAS-3 results.

SPM scores decreased across all eight constructs from Visit 1 (baseline) to Visit 2 (immediately post-intervention), with statistically significant changes in raw scores and T-scores for the Social Participation, Hearing, Touch, Balance and Motion, Planning and Ideas, and Total Sensory Systems constructs. Scores also decreased across all constructs from Visit 1 to Visit 3, with statistically significant changes in raw scores for the Social construct and raw scores and T-scores for the Hearing, Touch, and Total Sensory Systems constructs. There were no significant differences between scores at Visit 2 and Visit 3. See Table 3 for SPM results.

PEDI-CAT (ASD) scaled scores increased between Visit 1 and Visit 2, with statistically significant changes in both domains measured - Daily Activities and Social/Cognitive. Scores in both domains improved between Visit 1 and Visit 3, but these improvements were not statistically significant. There were no significant changes between Visit 2 and Visit 3. See Table 4 for PEDI-CAT results.

Table 3. SPM results.

Construct	Raw Score Visit 1 / T-Score Visit 1	Raw Score Visit 2 / T-Score Visit 2	Raw Score Visit 3 / T-Score Visit 3	Raw Score P-value (Visit 2 vs. Visit 1) / T-Score P-value (Visit 2 vs. Visit 1)	Raw Score P-value (Visit 3 vs. Visit 1) / T-Score P-value (Visit 3 vs. Visit 1)
Social Participation	29.33 (5.43)	23.83 (3.02)	24.16 (3.66)	0.007*	0.018*
	70.33 (6.44)	63.16 (4.75)	63.00 (7.63)	0.014*	0.065
Vision	20.67 (7.15)	18.34 (6.50)	18.50 (3.66)	0.420	0.206
	63.50 (7.92)	61.83 (6.44)	61.67 (6.74)	0.554	0.435
Hearing	23.83 (4.31)	14.00 (2.79)	13.50 (3.44)	0.000*	0.001*
	75.00 (4.34)	63.33 (4.63)	60.67 (8.02)	0.002*	0.007*
Touch	25.67 (4.63)	19.50 (0.75)	17.50 (3.31)	0.000*	0.002*
	70.33 (4.13)	63.83 (1.05)	59.83 (5.36)	0.000*	0.005*
Body Awareness	22.33 (8.55)	18.66 (6.12)	19.33 (3.74)	0.202	0.107
	64.67 (13.35)	61.17 (5.75)	61.84 (3.43)	0.196	0.099
Balance and Motion	21.33 (7.66)	17.50 (2.99)	18.66 (3.78)	0.026*	0.144
	63.83 (14.27)	59.00 (3.54)	62.33 (8.34)	0.021*	0.678
Planning and Ideas	27.17 (5.27)	22.00 (4.31)	22.00 (5.42)	0.032*	0.067
	73.00 (6.93)	66.17 (6.34)	65.33 (9.03)	0.046*	0.092
Total Sensory System	124.17 (32.07)	96.67 (13.44)	95.34 (8.45)	0.004*	0.000*
	70.67 (6.83)	63.34 (3.67)	62.34 (4.37)	0.005*	0.006*

Mean (standard deviation), * = statistically significant, α = 0.05, white rows indicate raw scores, gray rows indicate T-scores

Table 4. PEDI-CAT Results.

Domain	Scaled Score Visit 1	Scaled Score Visit 2	Scaled Score Visit 3	Scaled Score P-value (Visit 2 vs. Visit 1)	Scaled Score P-value (Visit 3 vs. Visit 1)
Daily Activities	53.83 (3.43)	56.00 (2.04)	56.50 (3.39)	0.048*	0.112
Social/Cognitive	61.17 (5.88)	64.50 (1.47)	62.84 (3.93)	0.005*	0.347

Mean (standard deviation), * = statistically significant, α = 0.05

Table 5. ATEC results.

Subscale	Score Visit 1	Score Visit 2	Score Visit 3	Score P-value (Visit 2 vs. Visit 1)	Score P-value (Visit 3 vs. Visit 1)
Speech/Language/Communication	8.00 (6.69)	6.67 (1.97)	7.67 (2.94)	0.158	0.793
Sociability	13.17 (10.42)	8.00 (5.00)	9.50 (2.34)	0.052	0.012*
Sensory/Cognitive Awareness	12.67 (9.07)	11.67 (4.24)	10.77 (3.25)	0.589	0.226
Health/Physical Behavior	24.00 (12.10)	17.50 (8.89)	18.50 (6.35)	0.133	0.087
Total	57.83 (34.61)	43.83 (13.25)	46.50 (10.88)	0.049*	0.051

Mean (standard deviation), * = statistically significant, α = 0.05

ATEC scores decreased across all subscales from Visit 1 to Visit 2, with a statistically significant decrease in total ATEC scores. Scores also decreased across all subscales from Visit 1 to Visit 3, with a statistically significant decrease in the sociability subscale. There were no significant differences between scores at Visit 2 and Visit 3. See Table 5 for ATEC results.

Discussion

Previous research has supported a possible connection between sound-based interventions, including music-based auditory stimulation like The Listening Program®, and improved sensory processing and/or behavioral responses to sensory input (Gee et al., 2015; Shahrudin et al., 2022; Simhon et al., 2019). The results of this study provide further support for this connection; participants had significant improvements across multiple sensory constructs from baseline to immediately post-intervention, suggesting the program had a positive impact on general sensory processing skills. Improvements in sensory processing skills from the intervention phase were relatively stable in the 3 month post-intervention phase, indicating positive changes were maintained over time.

Notably, participants in this study had statistically significant improvements in the Hearing construct of the SPM immediately after intervention and 3-months post-intervention. These findings provide support for use of The Listening Program® SPECTRUM with Waves™ bone conduction headphones to decrease hypersensitivity to sound for children with ASD and auditory SOR. In addition, parents shared observations during phone calls with the primary investigator that provided anecdotal evidence for decreased auditory SOR. For example, one parent reported her child covered his ears about 30% less, another parent reported her child stopped having meltdowns due to sounds, and another reported her son could now tolerate the sound of a hand dryer and use public bathrooms.

These results build on the findings of Gee et al. (2015), who noted positive trends for less sensory dysfunction on the Hearing construct of the SPM after using The Listening Program® for 2 of the 3 participants in their study. In the current study, all 6 participants demonstrated decreased scores (indicating less dysfunction) in the Hearing construct after using The Listening Program® SPECTRUM with Waves™ bone conduction headphones. All participants had “Definite Dysfunction” in the Hearing construct at baseline; 2 of 6 improved to “Typical” and 3 of 6 improved to “Some Problems” during the study.

Interestingly, participants in this study demonstrated statistically significant improvements in social skills (as measured by the SPM, ATEC, and PEDI-CAT) and communication skills (as measured by the ABAS-3). Again, parent observations provided some anecdotal evidence for improved social and communication skills. One parent reported her child began using more spontaneous speech after implementing The Listening Program®. Another parent observed that her son became more attentive, gained 3 additional words, and started enjoying singing songs like “Old MacDonald” after using the program. One participant’s teachers told his mother he seemed more engaged in class, without knowledge of this study or his use of The Listening Program®. As mentioned previously, avoiding sounds can limit opportunities to develop social and communication skills. The reverse is likely true as well—accepting sounds may facilitate development of social and communication skills.

After intervention, participants demonstrated significantly fewer behaviors common to children with ASD (as measured by the ATEC) and significantly improved functional skills (as measured by the PEDI-CAT). A positive trend for improvements in overall adaptive functioning emerged (as measured by the ABAS-3), but these changes were not statistically significant. Adaptive functioning requires skills in multiple domains, including cognition, executive function, and motor proficiency in addition to social skills, effective communication, and ability to process and interpret sensory information.

This study’s findings provide support for use of The Listening Program® SPECTRUM with Waves™ bone conduction headphones to improve sensory processing and reduce hypersensitivity to sound, which may lead to better social, communication, and functional skills for children with ASD and auditory SOR. However, ASD is a complex condition with core deficits beyond sensory processing differences. Therefore, interventions addressing primarily sensory systems (such as music-based auditory stimulation) are likely only a “piece of the puzzle” for improved adaptive functioning.

Limited treatment options are available for children with ASD and auditory SOR. Music-based auditory stimulation is a noninvasive treatment that can be completed with caregiver supervision. The study team expected some families to have difficulty maintaining use of the program for the long intervention period (about 10 months), but most families were able to incorporate listening sessions into their daily routines. Some families reported missing sessions when regular routines were disrupted (extended vacations, illness, or other reasons) and needed to reimplement parts of the program, as outlined in manufacturer guidelines. It is important to note that families who opted to participate in this study were interested in using The Listening Program® at home and had a caregiver available to supervise listening sessions. Incorporating listening sessions regularly at home or school could be more difficult for the broader population. However, compared to more intensive, hands-on interventions, music-based auditory stimulation is relatively affordable and feasible to implement in home or school environments.

Limitations and future research

Participants were diagnosed with ASD by various providers in their communities; therefore, assessment instrumentation and severity level were unknown to the study team. Preliminary data from this study suggest that children who scored in the "Extremely Low" category on the ABAS-3 at baseline (suggesting low adaptive functioning and likely increased severity of ASD) made less improvement on the SPM compared to children who scored in the "Low," "Below Average," or "Average" categories on the ABAS-3 at baseline. It may be that children with less severe levels of ASD benefit more from music-based auditory stimulation than children with more severe presentations, but further research is needed to explore this relationship.

Various underlying conditions can contribute to auditory SOR, including hyperacusis, phonophobia, and misophonia. For people with ASD, these conditions are often grouped together under the umbrella of auditory SOR. However, each is a separate condition with different diagnostic criteria. This study did not identify if children had underlying conditions leading to auditory SOR, such as hyperacusis, phonophobia, and/or misophonia. Future research should consider comparing outcomes across auditory SOR conditions.

All outcome measures in this study were completed by parent report. The focus of this study was on behavior and adaptive skills in 5—10 year-old children, therefore parents provided important insight and feedback about their children's daily lives and perceived changes in function. However, reliance on parent-reported outcome measures could have introduced expectancy and social desirability bias. Parent ratings on post-treatment questionnaires may have reflected expectations or hopes for improvement, rather than objective change. Parents may have felt implicit pressure to report outcomes that reflected positively on their decision to participate in this study. Future studies may consider including data from other individuals who interact regularly with participants, such as asking teacher to complete the Classroom Form of the SPM. There are limited options for clinical assessments of performance of sensory, behavior, or adaptive skills for our target population, but future studies may consider methods such as Goal Attainment Scaling or structured coding of observed adaptive behaviors to provide more objective data.

This study had a long intervention period, did not include a control group, and participants were able to continue any current therapies; consequently, changes could have occurred due to maturation, behavioral interventions, occupational therapy, or speech therapy. However, the 2 participants who were not receiving any traditional therapies during the study period made similar or better improvements compared to the 4 participants who did receive therapies during the study period. No participants were female, so results cannot be generalized to girls with ASD and auditory SOR.

The statistical analysis for this study was exploratory, therefore multiple test adjustments were not completed. Without adjustment, the risk for a type I error increases. However, given the number of t-tests completed, using a Bonferroni multiple test adjustment would have been overly conservative and substantially increased the risk of Type II error. Given the findings from this study, future studies may choose to narrow focus to changes in sensory processing, social, and communication skills rather than broadly measuring adaptive function.

More rigorous studies using larger samples, randomized designs, and control groups need to be completed to determine if changes are due to music-based auditory stimulation, maturation, or other variables. Did the positive changes seen in this study occur due to listening to SPECTRUM music with bone conduction headphones, or would listening to any music with any headphones for a similar dosage achieve similar benefits? The findings from this study support investment in larger trials to provide stronger empirical evidence for the effectiveness of The Listening Program® SPECTRUM with Waves™ bone conduction headphones to reduce hypersensitivity to sound and improve adaptive life skills for children with ASD and auditory SOR.

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