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A Pilot Study of Integrated Listening Systems for Children With Sensory Processing Problems

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*This pilot study explored the effects of Integrated Listening Systems (iLs) Focus Series on individualized parent goals for children with sensory processing impairments. A nonconcurrent multiple baseline, repeated measure across participants, single-case study design was employed (*n = 7*). The 40-session intervention was delivered at home and in the clinic. Individualized family goals served as the repeated measure. Exploratory analyses included the evaluation of physiological arousal. Participants showed improvement in home and education-related goals. Changes in physiologic arousal were noted in five of seven participants. Standardized scales demonstrated sensitivity to change. Thus, the iLs program may be beneficial for school- or clinic-based intervention.*

Keywords sound therapy, treatment effectiveness, auditory processing, sensory processing disorder, rehabilitation

Introduction

Sensory processing and integration problems exist when sensory signals do not result in appropriate responses (Miller, Anzalone, Lane, Cermak, & Osten, 2007). A person with sensory impairments finds it difficult to process and act upon information received through the senses, which creates challenges in performing everyday tasks and daily routines (Bar-Shalita, Seltzer, Vatine, Yochman, & Parush, 2009; Bundy, Shia, Qi, & Miller, 2007; Cohn, Miller, & Tickle-Degnen, 2000; Cosbey, Johnston, & Dunn, 2010). Motor clumsiness, behavioral problems, anxiety, depression, school failure, and other impacts may result if the symptoms are not treated effectively (Miller, 2006).

The standard treatment for children with sensory processing challenges is individual occupational therapy (OT) designed to enhance the child's ability to participate in daily activities and routines. The method used for treatment is individually defined and involves the remediation of underlying sensory impairments that enable participation in daily life at home and in education-related activities at school. Typically session duration is 30 to

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50 minutes, occurring two to three times per week (Miller, Schoen, James, & Schaaf, 2007; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2013). However, anecdotal evidence and intervention studies suggest that intensive programs produce more significant and lasting improvements (Granpeesheh, Tarbox, & Dixon, 2009). Sound-based intervention is one form of intensive therapy that is sometimes offered to children with sensory impairments by clinic and school-based occupational therapists to supplement traditional approaches (Bazyk, Cimino, Hayes, Goodman, & Farrell, 2010; Hall & Case-Smith, 2007). Also referred to as auditory programs, this form of treatment has widespread use but with limited empirical validation.

Effects of Auditory Programs

Previous treatment effectiveness research for children with sensory processing challenges has focused on sensory integration treatment to address the individualized needs of the child (May-Benson & Koomar, 2010; Miller et al., 2007; Pfeiffer et al., 2011; Schaaf et al., 2013; Watling, Deitz, Kanny, & McLaughlin, 1999). However, since occupational therapists often use auditory programs that involve listening to processed musical selections designed to supplement other sensory-based strategies (Bazyk et al., 2010; Hall & Case-Smith, 2007), evaluation of their effectiveness is warranted. Auditory programs are growing in popularity and are used in addition to traditional OT because services can speed progress and can be implemented at home or school, thus, increasing intensity of service (Bazyk et al., 2010; Carley, 2013; Hall & Case-Smith, 2007; May-Benson, Carley, Szklut, & Schoen, 2013; May-Benson & Koomar, 2010).

In spite of the evidence supporting the beneficial effects of listening to music (Jing & Xudong, 2008; Labbé, Schmidt, Babin, & Pharr, 2007; Lai & Good, 2005; Overy, 2003; Sarnthein et al., 1997), controversy still exists regarding the effects of therapeutic auditory programs that use acoustically modified music. A meta-analysis conducted in 1999 (Gilmor) reported positive gains in linguistic skills, psychomotor skills, personal and social adjustment skills, auditory skills, and cognitive skills following use of a specific type of auditory program called the Tomatis Method. However, the conclusions from the meta-analytic study were limited by the characteristics of the original studies. A more recent study of the Tomatis approach (Corbett, Shickman, & Ferrer, 2008) did not show statistically significant differences between the placebo and Tomatis treatment. Yet this study has also been criticized for methodological flaws (Gerritsen, 2010). Although not a scientifically rigorous study, Ross-Swain (2007) reported better comprehension, memory, and ability to follow directions following use of the Tomatis Method in a group of children who had auditory processing problems.

Mixed results were also demonstrated for use of another auditory program, Auditory Integration Training (AIT: aka the Berard method). Although several studies suggested limited benefits (Edelson et al., 1999; Rimland & Edelson, 1994, 1995), these studies also had important methodological weaknesses. Four well-controlled studies of AIT failed to find any behavioral improvement (Bettison, 1996; Gillberg, Johansson, Steffenburg, & Berlin, 1997; Mudford et al., 2000; Zollweg, Palm, & Vance, 1997), the most recent of which found no benefit of AIT over a control condition on measures of IQ, of comprehension, or of social adaptive behavior (Mudford et al., 2000). In a systematic review of six randomized controlled trials, Sinha, Silove, Wheeler, and Williams (2006) concluded that there was not enough evidence to support the use of AIT.

Three studies of auditory intervention programs have been published in the occupational therapy literature. One was a case study (Nwora & Gee, 2009) and the other (Hall

& Case-Smith, 2007) reported improvement only when the intervention was combined with a sensory diet that was poorly described and not manualized. The third study (Bazyk et al., 2010), implemented in a preschool setting, found an accelerated rate of development on standardized measures; however, the results were confounded because participants continued to receive routine occupational therapy intervention during the study.

Arousal Mechanisms

Many of the reported outcomes of auditory programs are hypothesized to be related to changes in arousal linked to activitation of the autonomic nervous system (Sollier, 2005). For the purposes of this paper, arousal is defined as "increased neuronal excitability that mobiizes the internal resources needed to maintain alertness" (p. 93). Classic theories of arousal assert that an appropriate level of arousal is necessary to support attention and enhance learning (Fischer, Langner, Birbaumer, & Brocke, 2008; Hebb, 1955). Thus, if changes in arousal occur following participation in an auditory program it may be relevant to understanding the underlying mechnaism of change. Drawing on this supposition, several speculations have been made as to the observed changes in arousal being due to (a) the calming effect of listening to music (Alvarsson, Wiens, & Nilsson), (b) the style of music being listened to (Roque et al., 2013), or (c) the person experiencing pleasure during music listening (Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009).

Arousal is frequently studied by measuring electrodermal activity (EDA), a physiologic measure used in the laboratory (Dawson, Schell, & Filion, 2000) in children with and without sensory processing challenges (Schoen, Miller, Brett-Green, & Nielsen, 2009). Only one previous study has explored changes in arousal following a sensory based intervention. That pilot study of the effectiveness of occupational therapy with children who had sensory processing challenges showed a decrease in electrodermal activity following intervention two times a week for 10 weeks (Miller, Coll, & Schoen, 2007). What is not known is whether arousal changes with auditory interventions.

Aims of the Study

Thus, the primary aim of this pilot study was to explore the effects of a newly developed auditory program, known as Integrated Listening Systems (iLs). Specifically, the Focus Series sensory motor program (heretofore referred to as the iLs program) combines listening to acoustically processed, low frequency music via air conduction and bone conduction with participation balance, movement, and visual-motor activities. Our research questions were exploratory in nature due to the lack of research using this program—specifically, (1) What individualized family goals are impacted following participation in the iLs program? (2) Does the iLs program produce changes in arousal? (3) Are standardized measures of behavior, emotion, and functional abilities sensitive to change, and (4) What are parents' qualitative experiences relative to the feasibility and utility of the iLs program?

Materials and Methods

Ethics Statement

The study received institutional review board approval from Rocky Mountain University of Health Professions and followed all standards set by the board. All participants' parents provided written consent, and participants above age 7 provided written assent. Following study participation, all families were allowed to keep the iLs system.

Research Design

This study employed a single-subject, nonconcurrent, multiple-baseline, repeated-measure-across-subjects, AB design in which A represented the baseline phase and B represented the intervention phase with a postintervention no-treatment phase. This design is a useful first step in treatment-effectiveness research seeking to establish a relationship between an individualized intervention and change in targeted outcomes (Bloom, Fischer, & Orme, 2006; Kennedy, 2005; Kielhofner, 2006). The subject serves as his or her own control, with performance of a subject prior to intervention compared to his or her performance during and after intervention. The nonconcurrent design offers greater flexibility in clinical settings because baseline data from the participants does not have to be collected concurrently (i.e., at the same time) (Harvey, May, & Kennedy, 2004; Kennedy, 2005). When repeated with multiple subjects, this design provides a cost-effective and systematic method for replication of results (Kennedy, 2005).

The repeated measure for this study was individualized behavioral goals. Each participant's data was collected for approximately 16 weeks. Baseline (A) was the control period. During this phase, the goals were scored by the parent each week, for each participant, over a 3- to 5-week period. The intervention phase (B), consisted of 40 one-hour sessions of the iLs program delivered 5 days a week over an 8-week period, four times at home and once at the clinic. Each week the goals were scored again by the parent. The postintervention phase consisted of 2 to 5 weeks of data collection on individualized goals to evaluate whether gains could be maintained when the intervention was stopped.

Instruments: Assessment Measures

Scale Assessment and Inventory. The Sensory Processing (SP) scale is a comprehensive assessment of Sensory Modulation Disorder. It has two parts: (1) the Inventory, which is an informant-based measure completed by parents/caregivers and (2) the Assessment, which is an examiner-administered performance measure (Schoen, Miller, & Sullivan, 2014). The SP Scale consists of three subscales: Sensory Over-Responsivity, Sensory Under-Responsivity and Sensory Seeking/Craving. Each subscale provides information about behavioral responses to sensory experiences across seven sensory domains (touch, vision, sound, movement (proprioception, vestibular), taste, and smell). Children and adults from ages 3 to 49 have been tested, with internal reliability $> .90$ and discriminant validity effect sizes > 1.0 (Schoen, Miller, & Green, 2008; Schoen et al., 2014). Used in combination with parent interview and clinical observation, this scale allows the clinician to characterize an individual's sensory processing impairments.

Tests for Auditory Processing Disorders in Children—SCAN-3:C. The SCAN-3:C (Keith, 2009) is a standardized assessment of auditory processing skills for children between the ages 5.0 to 12.11. The three diagnostic tests, Filtered Words, Competing Words and Competing Sentences were used to characterize the sample and to screen for auditory processing challenges. These tests had high internal reliability and test—retest reliability and therefore were used for this study to screen for auditory processing challenges. Validity data support the use of the SCAN-3:C largely for screening purposes (Keith, 2009).

Outcome Measures

Individualized Goals: Visual Analog Scale. Individualized family goals were constructed for each participant following the parent interview. Each goal was converted into a Visual Analog scale (VAS) by the lead investigator and was stated in a positive direction along a 5-inch horizontal line ranging from 1, indicating that the behavior occurs *none of the time*, to 5, indicating that the behavior occurs *all of the time*. For example, Ability to Follow Directions was a goal for six out of seven participants. The VAS was the repeated measure recorded weekly for the entire 16 weeks. VAS has been found to be a reliable and valid measure of a variety of subjective phenomena (Wewers & Lowe, 1990) and is one of the most commonly used paradigms in the study of pain (Jensen, Chen, & Brugger, 2003). The VAS was scored by measuring the distance in inches (to the closest 32nd of an inch) from the beginning end of the scale to the parent's mark on the line.

Arousal Measures: Sensory Challenge Protocol. The Sensory Challenge Protocol (Miller et al., 1999) is a well-studied standard psychophysiologic laboratory paradigm that has been in use since 1995 (Hagerman et al., 2002; McIntosh, Miller, Shyu, & Hagerman, 1999; Miller, Reisman, McIntosh, & Simon, 2001).

Electrodermal activity is obtained using the palmar electrodes supplied with PSYLAB (Contact Precision Instruments, Cambridge, MA). The PSYLAB software program collects EDA measures of arousal at rest during baseline and recovery when the child sits quietly and no stimuli are presented. Skin conductance level is recorded in microSeimans (μS). During the stimulation phase of the experiment, EDA amplitudes reflective of sensory reactivity are recorded for responses that are $> .02\ \mu$S and occur between 0.8 and 4.0 seconds after each stimulus.

EDA data is collected continuously in three phases: (1) a 3-minute baseline phase with no stimuli presented; (2) eight trials of sensory stimuli (presented for 3 seconds at a pseudorandom interstimulus interval of 10 or 15 seconds) across six sensory domains—auditory (tone and siren), visual (strobe light), olfactory (wintergreen), tactile (feather), and vestibular (chair tip); and (3) a 3-minute recovery period with no stimuli.

Standardized Measures: Adaptive Behavior Assessment System-II. The Adaptive Behavior Assessment System (ABAS; Harrison & Oakland, 2003)is a norm-referenced report measure designed to assess adaptive behavior in individuals from birth to age 89 years. The scale includes 10 adaptive skill areas from which four composite scores are derived: (1) conceptual composite (e.g., communication, functional academics, and self-direction); (2) social composite (e.g., leisure and social skills); (3) practical composite (e.g., self-care, home living, community use, and health and safety); and (4) general adaptive composite (e.g., the sum of all adaptive skill areas). The parent/primary caregiver form was used in this study and the composite scores and subtest scores were computed to monitor progress over time. Internal reliability is reported to be high for the composite scores, the adaptive domains, and all skill areas (Harrison & Oakland, 2003). Similarly strong evidence of content and concurrent validity is reported (Harrison & Oakland, 2003).

Standardized Measures: Behavior Assessment System for Children-2. The Behavior Assessment System for Children-2 (BASC-2) Reynolds & Kamphaus, 2004) is a multidimensional/multimethod system for assessing children's social, emotional, behavioral, and adaptive functioning. The parent rating form was used in this study. It consists of a clinical profile, which has nine scales that are used to compute the three composite scores: externalizing, internalizing, and behavior symptom index. The adaptive profile comprises five scales that make up the adaptive skills composite. Composite scores and subscale scores were used in this study to measure progress. It is reported that composite scores have stronger internal reliability than the individual scales and have strong construct, convergent, and divergent validity (Reynolds & Kamphaus, 2004).

Participants

Seven children and their families participated in this study. The study was conducted at a private clinic in Greenwood Village, CO. Participants were recruited through posted invitation letters from the center. Interested parents signed a form consenting to be contacted. Children were selected if they met inclusion criteria and families were willing to postpone participation in other interventions (e.g., occupational therapy, speech therapy) for the duration of the study. All parents reported that their child had challenges in daily activities at home and school but had not received previous treatment for sensory issues.

Inclusion criteria were: (1) significant sensory processing impairments reported to be interfering with performance at home or school based on parent report on the Sensory Processing Scale Inventory, parent interview, and confirmation by an occupational therapist trained in using the Sensory Processing Scale Assessment and Inventory; (2) between ages 4 and 18; (3) an intelligence level of "within normal limits" as determined by school aptitude tests; (4) parent report of auditory over-responsivity and/or auditory processing problems and normal hearing; and (5) parent/child willingness to commit to the time and scheduling requirements of the study protocol.

Exclusion criteria were the presence of comorbid disorders such as a seizure disorder, bipolar disorder, deafness, physical disabilities (e.g., cerebral palsy), or neurological impairments; participation in other therapies during the time of the study; and an inability to tolerate wearing headphones for the designated 60 minutes required by the study design.

Four males and three females ranging in age from 5 to 12 years participated in the study. All were Caucasian; socioeconomic status was defined by the education level of the mother—all had at least a high school degree). Interpretation of findings by the evaluating occupational therapist confirmed the presence of tactile and auditory over-responsivity as reported by on the SP Scale Inventory and observed on the SP Scale Assessment for all participants. Three participants also had symptoms of sensory craving behavior and one participant had symptoms of sensory under-responsivity based on the above measures. Four out of seven participants had atypical scores on two subtests of the SCAN-3:C (e.g. scores $<$ 1 standard deviation below the mean) suggestive of auditory processing challenges. The other three participants scored within the typical range for auditory processing. No other comorbid diagnoses were reported.

Procedures

Three stages constituted the study: (1) administration of the pretest measures, (2) baseline and intervention, and (3) return to baseline, post-testing, and follow-up.

Stage 1. Administration of the pretest measures. Participants first completed the Sensory Processing (SP) Scale Assessment and Inventory in order to fully characterize their sensory processing challenges. The SCAN-3:C was also administered to screen for auditory processing difficulties. A parent interview–goal-setting session was conducted in order to establish the individualized goals for the visual analog scale (VAS) that served as the repeated measure. Pretest measures also included all standardized parent report questionnaires and administration of the Sensory Challenge Protocol Laboratory.

Stage 2. Baseline and intervention. The second stage began with a 3- to 5-week baseline phase (A) during which individualized VAS goals were determined (where the iLs program was not used). Goals whose baselines were unstable could not be extended due to restrictions in participant schedules and, therefore, were not included in the study. Next came the intervention phase (B), which consisted of 40 sessions of the iLs program. The program was administered four times a week at home by the parent and once a week at the clinic by the same research assistant (RA; intervention defined later).

Stage 3. Return to baseline. The final phase of the study (A) was a 2- to 4-week–return-to-baseline period of no intervention, post-testing of all standardized parent report questionnaires, and re-administration of the Sensory Challenge Protocol Laboratory. At this time, parent reactions to participation in the study were solicited, including feasibility and utility of the iLs program as well as subjective changes noted in their child not elicited by the individualized goals or report questionnaires.

Description of the Intervention

The intervention consisted of 40 sessions using the iLs Focus Series sensory motor program. The iLs program is a protocol that uses specific classical music selections that are heard each day. The program is loaded onto an Apple iPod and delivered through a miniamplifier with adjustable air- and bone-conduction volume to Sennheiser headphones custom fitted with bone-conduction capability. Specifically, the sensory motor program emphasizes frequencies at 750 Hz and lower. The iLs music is processed such that different frequencies in each selection are enhanced or dampened. An additional process shifts subtle volume changes from the right-ear channel to the left-ear channel. Both of these alterations to the musical selections are designed into the iLs program in a graded fashion, beginning gently and gradually increasing as the program progresses.

Intervention included listening to the preprogrammed music 5 days a week for 60 minutes. Each program had a specific listening schedule accompanied by visual motor activities performed during the first 15 to 20 minutes of each session that were selected from the Playbook manual and user guide. The sets of activities included balance and core, ball and bean bag, and eye-hand coordination games. The rest of each session was spent doing child-selected motor activities; creative and/or relaxing activities such as drawing, painting, puzzles, building with blocks, and playing cards; or just sitting in a comfortable chair.

Intervention sessions were completed by the RA once a week in the clinic and by the parent 4 days a week at home. Training to the RA and parents in the use of the iLs listening components as well as in the selection and administration of Playbook visual-motor activities was provided by the lead investigator. A program tracker was completed for each participant's clinic sessions and home sessions to ensure compliance with and fidelity to the program. Intervention fidelity was also ensured through weekly meetings of the RA and the lead investigator and of the RA and participants' parents to discuss intervention administration, manual adherence, and plans for subsequent sessions.

Parents did not pay for the intervention nor were they required to purchase the iLs unit in order to participate in the study.

Data Collection

Preintervention data were collected during the participant's first visit. Included were the Sensory Challenge Protocol and the caregiver report questionnaires. The visual analog scale (VAS) goals were developed by the lead investigator following the first parent meeting. Baseline data were collected on the VAS goals via parent report once a week over a 3- to 5-week period prior to initiating the intervention. Each week during the participant's visit to the clinic in the intervention phase, parents returned to the RA the score for each week's VAS goals (parent's mark along the 5-inch line). Postintervention data were collected on the VAS goals using the same procedure as during the baseline phase. Participants returned 2 to 4 weeks following intervention to participate in the Sensory Challenge Protocol and for parents to complete the caregiver report measures and provide subjective feedback on the feasibility and utility of the iLs program.

Data Analysis

Owing to the small sample size and the variables' non-normal distribution (Kolmogorov-Smirnov test, $p < .1$), nonparametric tests were utilized for all statistical analyses described in the next sections (i.e., individualized goals and standardized measures).

Individualized Goals. VAS goals were converted into numeric scores by measuring the distance in inches (to the closest 32nd of an inch) from the beginning end of the scale to the parent's mark along the line. Each goal for each participant, from baseline to postintervention, was plotted on a graph.

Several methods of data analysis were used. Data for individualized VAS goals were examined to determine whether a stable or declining pattern was established during baseline. As is recommended in multiple baseline research, only goals that have a baseline period meeting the following criteria should be included in the intervention phase of a study (Engel & Schutt, 2014): (1) performance that has a relatively stable pattern (no improvement) with little variability; (2) a slope less than .1; or (3) a linear downward trend based on a linear regression analysis. Each participant had at least one goal that met these criteria.

Initial investigation of VAS goals was based on visual analysis of the data. VAS goal data were plotted across phases of the study and analyzed in terms of three dimensions recommended by Kennedy (2005). The first dimension examined was *level*, referring to the mean of the data within a condition. The second dimension examined was *trend* (or *slope*), which refers to the best-fit straight line for the data within each condition. The descriptors low, medium, and high are assigned to describe the size of the slope. The third dimension examined was *variability* of the data, which reflects the degree to which the data points deviate from the best-fit straight line. Variability is a qualitative descriptor like trend, which is classified as high, medium, or low (Kennedy, 2005). Patterns of goal achievement were similar within each participant; therefore, the data depicted in Figure 1 is the mean goal performance for each participant across phases of the study. To evaluate these changes in parent-prioritized goals, the Wilcoxin matched-pairs–signed-rank test was used to determine whether differences in *level* and *slope* of VAS goal scores changes were statistically significant.

Arousal Measures. To evaluate physiologic changes, difference scores were computed comparing pre- and postadministration of the Sensory Challenge Protocol. Variables

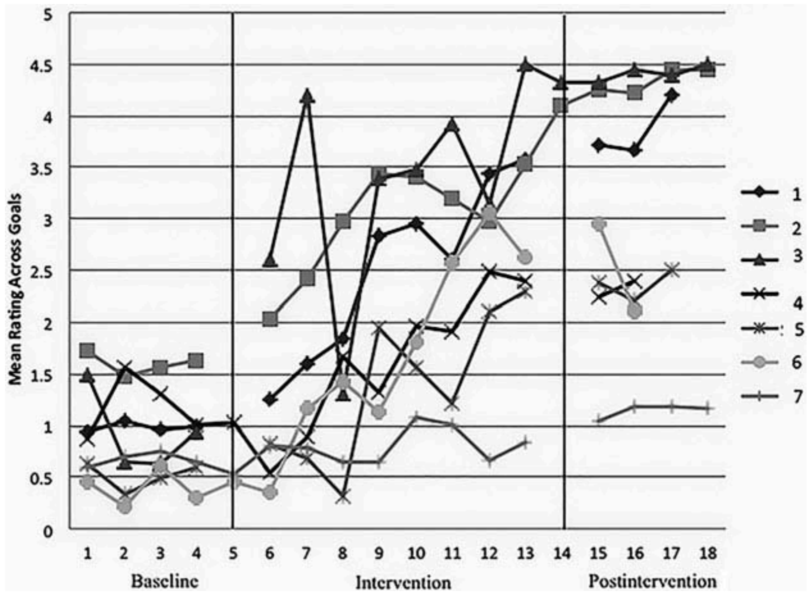

Figure 1. Individual mean goal performance across time.

included the average difference in amplitude by sensory domain and the average difference in EDA during baseline and recovery.

Standardized Measures. To further evaluate parent perceptions of changes over time, the Wilcoxin matched-pairs–signed-rank test was used to evaluate differences on both the BASC and the ABAS, pre- versus postintervention. Analyses were considered exploratory and designed to inform future studies; therefore, no correction for multiple comparisons was made.

Qualitative Experiences. Subjective feedback from parents on the feasibility and utility of the iLs program was aggregated and summarized by the first author.

Results

Individualized Goals

Participant goals demonstrated some commonality: six of seven participants had a goal involving "following directions" and five of seven participants had a goal involving "completing a task" (e.g., homework, morning routine, cleaning room) in a timely manner and without incident. Other parent goals related to emotion regulation, frustration tolerance, and social participation with siblings or peers (see Table 1 for a complete list of goals).

Eight goals were discarded prior to the initiation of intervention because they did not meet criteria for a stable or declining baseline pattern. One participant had a single remaining goal; all other participants had between three and six goals. A total of 28 goals were evaluated. With respect to 23 of the 28 goals, participants demonstrated a positive change in level from baseline to intervention, which was sustained or increased after intervention. The five goals that showed minimal change were for participant 7 (e.g., $< .3$

Table 1
Mean Level and Slope by Study Phase

Goals by participant	Baseline mean	Intervention mean	Postintervention mean	Baseline slope	Intervention slope	Postintervention slope
Participant 1						
Follows verbal directions	0.96	2.20	3.26	0.01	0.30	0.52
Sleeps without waking to external noise	0.99	2.48	4.19	−0.03	0.33	0.17
Not distracted by outside noise	1.01	2.86	4.13	0.06	0.35	0.04
Participant 2						
Follows multistep verbal directions	1.60	3.12	4.35	−0.02	0.19	0.08
Participant 3						
Completes morning routine without incident	1.42	3.18	4.37	0.00	0.14	0.05
Has adequate nutritional intake throughout the day	1.08	2.93	4.42	−0.11	0.31	0.05
Completes spelling work in a timely manner	0.38	3.78	4.41	−0.30	0.16	0.05
Completes writing assignments without emotional incident	0.80	3.82	4.47	−0.09	0.18	0.03
Participant 4						
Completes homework in a timely manner	0.55	1.65	1.98	−0.02	0.35	0.29
Understands what mother is saying	1.39	1.71	2.16	−0.19	0.26	−0.50
Experiences less frustration	2.05	1.65	2.72	0.08	0.28	0.12
Emotionally is not too hard on self	0.62	1.58	2.41	0.04	0.19	0.66

(*Continued*)

Table 1
(Continued)

Goals by participant	Baseline mean	Intervention mean	Postintervention mean	Baseline slope	Intervention slope	Postintervention slope
Participant 5						
Gets dressed in morning without incident	0.62	1.64	3.07	0.05	0.31	−0.02
Does not misinterpret others' behavior	0.37	1.17	2.78	0.06	0.17	0.13
Follows directions within a timely manner	0.63	1.09	1.99	−0.01	0.16	0.38
Understands sarcastic statements	0.72	1.26	2.22	−0.07	0.22	0.31
Fully comprehends what he reads out loud	0.33	1.47	1.83	−0.09	0.24	−0.31
Does not get frustrated when reading	0.42	1.57	2.30	0.07	0.32	−0.13
Participant 6						
Follows multistep directions	0.34	1.63	2.48	0.06	0.34	−0.33
Cleans up his room	0.41	1.62	2.34	0.02	0.36	−0.95
Has legible handwriting	0.30	1.88	3.01	−0.06	0.35	−1.07
Puts things where they belong	0.56	1.95	2.31	0.01	0.36	−1.08
Participant 7						
Allows touch from family members	0.37	0.78	0.93	−0.02	−0.07	−0.08
Displays flexibility in play	0.84	0.88	1.07	0	0.05	0.01
Keeps bedroom organized	0.43	0.53	0.99	−0.01	0.02	0.16
Gets through morning routine in a timely manner	0.53	0.70	1.24	−0.03	0.00	0.11
Willingly participates in physical activities	0.79	1.06	1.26	0.01	−0.06	−0.26
Gets through school work in a timely manner	0.91	0.93	1.37	0.02	−0.01	0.28

change in level from baseline to intervention). Participant 4 had one goal that decreased slightly (e.g., "experiences less frustration") (levels are depicted in Table 1). The data continued its upward trend from baseline to intervention for all participant goals but the magnitude of the slope varied. During the intervention phase, 11 of the 28 goals had medium-positive-magnitude slopes (e.g., $> .3$), suggesting a gradual increase; while 13 of the 28 goals had a low-magnitude slope (e.g., $< .19$), suggesting a more slowly increasing trend. Participant 6 had declining/negative slopes in the postintervention phase although the overall level of goal achievement was higher compared to baseline. Slopes for participant 7 remained relatively flat from baseline to intervention, with little change in level. In the postintervention phase for this participant, levels increased for all six goals and slopes gradually increased for three of the six goals (e.g., a low-magnitude slope). High variability was noted for participant 3 during the intervention phase of the study. A fluctuating pattern of improvement was evident across her goals, with an initial large improvement in three out of four goals that had low-magnitude slopes. For this participant, gains were sustained into the postintervention phase for all of these goals.

To evaluate whether there was a significant difference between baseline goal performance and goal performance during intervention, the Wilcoxin matched-pairs–signed-rank test (as data was nonparametric) was used. A significant difference was found between level at baseline ($M = .76$; $SD = .43$) and level during intervention ($M = 1.82$; $SD = .91$) across all participants ($z = -4.46$; $p < .001$). A significant difference was also obtained between slopes at baseline ($M = .02$; $SD = .08$) and slopes during intervention ($M = .21$; $SD = .13$) across all participants ($z = -4.49$; $p < .001$). After intervention, participants continued to improve with respect to 19 of the 28 goals (see Table 1).

Arousal Mechanisms

One participant had incomplete data due to equipment failure during the postintervention administration of the Sensory Challenge Protocol; therefore, there is missing posttest data for wintergreen, feather, chair tip, and recovery. Table 2 depicts the mean difference between pretest and post-test scores for amplitude of EDA by domain and EDA at baseline and recovery. Three of seven participants had a reduction in EDA to 2 to 4 of the sensory challenges, both of which involved the two sound stimuli. Both increases and decreases in EDA for baseline and recovery were noted. Four of the seven participants had a reduction in EDA from pretest to post-test at either baseline or recovery, and two had an increase in EDA from pretest to post-test for both baseline and recovery.

Table 2
Mean and Changes in Arousal from Pre- to Postintervention

Participant	Baseline	Recovery	Tone	Strobe	Siren	Winter-green	Feather	Chair tip
1	−12.67		−1.44	−1.05	−1.05			
2	−6.33	−9.13	−0.20	−0.31	−0.05	−0.30	−0.21	0.01
3	−1.04	−0.93	−1.29	−0.58	−1.04	−1.19	−0.33	0.92
4	−0.38	−0.40	−1.85	−0.42	−1.31	−0.54	−0.06	0.68
5	8.68	11.47	0.09	0.04	0.08	0.02	−0.01	−0.31
6	−0.38	−1.67	−0.31	0.04	−0.14	0.00	0.00	0.29
7	1.98	2.25	0.13	0.12	−0.20	−0.55	−0.43	−0.29

Standardized Scales

Analyses were conducted to determine which standardized measures might be useful for future study of the effectiveness of the iLs program. Subtests and composite scores of the Adaptive Behavior Assessment System (ABAS) and Behavior Assessment System for Children (BASC) were explored. All of the dimensions of the BASC changed in the predicted direction with the Wilcoxin matched-pairs–signed-rank test showing significant changes in all the composite scores of the BASC (e.g., Externalizing, Internalizing, Behavioral Symptoms Index, and Adaptive Skills) and in seven of the total 13 subtests, including the following: Hyperactivity, Aggression, Anxiety, Depression, Atypicality, Adaptability, and Activities of Daily Living. All the composite scores and subtests of the ABAS changed in the predicted direction; however, statistically significant changes were found in only two of the seven subtests: Communication and Self-care. (See Table 3 and Table 4).

Table 3
Changes in BASC Subtest and Composite Standard Scores

	Intervention				
	Pre ($n = 7$) M (SD)	Post ($n = 7$) M (SD)	Wilcoxin matched pairs	p	Effect size
Clinical subtests and composites ($M = 50$; $SD = 10$)					
Externalizing composite	62.14 (15.31)	52.86 (11.44)	−2.20	0.03	0.69
Hyperactivity	61.43 (16.72)	52.14 (13.21)	−2.20	0.03	0.62
Aggression	62.71 (15.68)	52.29 (9.57)	−2.37	0.02	0.80
Conduct problems	58.00 (13.28)	54.67 (10.93)	−1.37	0.17	0.27
Internalizing composite	56.43 (11.39)	46.29 (7.89)	−2.20	0.03	1.03
Anxiety	60.57 (16.37)	52.71 (10.34)	−1.99	0.04	0.57
Depression	59.29 (12.47)	46.14 (7.47)	−2.20	0.03	1.28
Somatization	46.14 (8.49)	42.57 (7.70)	−0.32	0.75	0.44
Behavioral symptoms index	60.43 (13.88)	49.71 (8.08)	−2.20	0.03	0.94
Atypicality	55.14 (11.14)	45.57 (3.99)	−2.03	0.04	1.14
Withdrawal	52.86 (12.56)	47.86 (11.85)	−1.57	0.12	0.41
Attention	56.29 (13.57)	54.71 (11.25)	−0.51	0.61	0.13
Adaptive subtests and composite ($M = 50$; $SD = 10$)					
Adaptive skills	45.29 (13.66)	49.71 (12.72)	−2.02	0.04	0.33
Adaptability	41.29 (15.21)	49.14 (13.84)	−2.26	0.02	0.54
Social	48.71 (16.43)	50.71 (14.45)	−1.10	0.27	0.13
Leadership	51.33 (10.86)	53.00 (7.64)	−0.73	0.47	0.18
ADL	44.71 (14.12)	47.57 (12.61)	−2.06	0.04	0.21
Communication	42.00 (16.17)	45.71 (13.61)	−1.68	0.09	0.25

Note. Higher scores are worse for all clinical subtests and composites. Higher scores are better for all adaptive subtests and composites.

Table 4
Changes in ABAS Subtest and Composite Standard Scores

	Intervention				
	Pre ($n = 7$) *M* (*SD*)	Post ($n = 7$) *M*(*SD*)	Wilcoxin matched pairs	*p*	Effect size
Subtests ($M = 10$, $SD = 3$)					
Communication	7.71 (3.40)	9.71 (3.55)	−2.41	0.02	0.58
Functional academics	7.29 (2.98)	8.43 (4.61)	−0.74	0.46	0.30
Self-direction	6.43 (3.91)	7.57 (4.50)	−1.29	0.20	0.27
Leisure	9.29 (1.70)	10.86 (3.49)	−1.69	0.09	0.57
Social	7.14 (3.49)	8.29 (4.23)	−0.96	0.34	0.30
Community use	9.14 (3.81)	9.86 (5.15)	−0.11	0.92	0.16
Home living	6.00 (3.51)	7.29 (4.68)	−1.05	0.29	0.31
Health and safety	8.14 (1.68)	9.86 (2.80)	−1.44	0.15	0.75
Self-care	5.71 (2.29)	8.57 (3.55)	−2.04	0.04	0.96
Composites ($M = 100$, $SD = 15$)					
General adaptive	84.71 (11.27)	93.43 (23.94)	−1.36	0.18	0.18
Conceptual	85.86 (13.50)	93.71 (22.13)	−1.78	0.08	0.43
Social	91.00 (11.97)	99.14 (19.16)	−1.36	0.18	0.51
Practical	85.57 (7.19)	94.71 (21.43)	−0.94	0.35	0.58

Qualitative Experiences

Gains reported by individual parents were as follows:

"His reading scores came up 4 levels";
"Her face seems more animated";
"She is able to joke with others";
"He sleeps better";
"He picks up on sarcasm more quickly";
"He is happier at school";
"The legibility of her handwriting improved"; and
"His behavior in school is better."

Discussion

Individualized Goals

This pilot study provides preliminary evidence that the iLs program is effective in ameliorating conditions for some of the children with sensory over-responsivity and auditory processing impairments. Notable changes were reported in parent-developed individualized child goals such as following directions, completing daily tasks (e.g., homework, morning routine, putting away belongings) in a timely manner, and reducing emotional outbursts—problems that affect functioning at home and school. These gains continued to be noted with respect to most of the goals (19 out of 28) into the postintervention phase.

Previous research reflects controversy as to the effectiveness of auditory programs. However, study has been limited to the Tomatis Method (Corbett et al., 2008; Gilmor, 1999; Ross-Swain, 2007); to Berard's Auditory Integration Training (Edelson et al., 1999; Gillberg et al., 1997; Rimland & Edelson, 1994, 1995); and to Therapeutic Listening (Bazyk et al., 2010; Hall & Case-Smith, 2007). This is only the second study to evaluate the use of the iLs program for children with sensory processing impairments. The iLs program is unique because it combines an individualized auditory program with visual and movement activities. The other study of the iLs program reported improvements in behavioral, emotional, and sensory regulation; social skills; and functional listening and communication in children ages 7 to 10 years with autism spectrum (unpublished data). Similar to that study, our study supports the effectiveness of the iLs program based on parent perceptions of improvement. Because parents' opinions as to the value of an intervention often determine what interventions they try and continue to use (Bowker, D'Angelo, Hicks, & Wells, 2011; Green et al., 2006), tapping their perceptions is critical to evaluating the effectiveness of an intervention. The effectiveness of the iLs program based on parent perceptions of the attainment of individualized goals established at the start of the study is an important outcome demonstrated by this study.

Research evaluating the optimal frequency and duration of the therapeutic interventions used by rehabilitation professions is also greatly needed (AOTA, 2011). Many studies suggest that children with sensory processing challenges should receive therapy two to three times a week over a period of at least 10 weeks (Miller et al., 2007; Pfeiffer et al., 2011; Schaaf, Benevides, Kelly, & Mailloux-Maggio, 2012; Schaaf et al., 2013). However, this study utilized the iLs program five times a week (for an hour) over an 8-week period. Parents had to attend the clinic only once a week (or 8 times) because they were able to administer the program at home on the other days. Thus, the iLs program may be a useful method of supplementing school or clinic-based intervention for some children with sensory processing challenges.

Arousal Mechanisms

To the best of our knowledge, this is the first study to report physiological changes using an auditory program that delivers processed music. Four participants showed a decrease in arousal level and two showed an increase in arousal following intervention. Unlike a previous study that found a reduction in anxiety levels following music listening but no change in physiological outcomes (Wang, Kulkarni, Dolev, & Kain, 2002), for the four participants in this study whose arousal decreased, the behavioral changes reported by their parents were also suggestive of reduced arousal. For example, parent reports included "He generally appears calmer"; "She seems more relaxed"; and "Meltdowns are less often and less lengthy." In addition, these participants also showed a reduction in parent-reported hyperactivity, aggression, anxiety, and depression as measured on the BASC. However, two participants showed an increase in physiological arousal. An alternative explanation comes from the music-listening literature which suggests that the experience of listening to familiar music may have become pleasurable and emotionally rewarding, thus, increasing rather than decreasing their arousal (Van Den Bosch, Salimpoor, & Zatorre, 2013).

This study also demonstrated changes in arousal in response to sensory challenges. Three participants showed a reduction in EDA to two or more sensory domains, reflecting decreased arousal with regard to that sensory domain. The two sensory domains that consistently elicited change among these participants were the tone and siren. Given that these participants at the start of the study were reported to be over-responsive to auditory stimuli, this finding is notable. One participant reported better sleep due to a reduction in auditory over-responsivity, and two reported having less difficulty filtering out background noise during daily interactions at home and school. Miller and colleagues (Miller, Coll, & Schoen, 2007) reported similar improvement in electrodermal activity (e.g., reduction in amplitudes to sensory challenges) in a small sample ($n = 4$) following a sensory-based intervention. Taken all together, the physiological findings from this study provide only preliminary information, which can be used for hypothesis generation in future studies.

Standardized Measures

Two standardized scales were evaluated to determine sensitivity in detecting improvements following intervention with the iLs program. The BASC showed potential for use in future studies. All four composite scores were sensitive to change, as were seven of the subtests. This finding suggests that the dimensions tapped by the BASC (e.g., behavioral and emotional characteristics of the individual) may be target areas, most affected by the iLs program However, only the Self-care and Communication subtests of the ABAS showed significant pre–post change during the study. This finding may be owing to chance because we did not correct for multiple comparisons, but it is noteworthy that the values for the Communication subtest of the ABAS changed in the predicted direction especially since four out of seven participants screened positive for auditory processing challenges prior to participation in the study. Further study is indicated but identifying specific measures that are sensitive to the outcomes of this intervention will decrease the likelihood of obtaining spurious findings in future studies.

Qualitative Experiences

In general, parents in this study were pleased with their child's results. Parent reactions that were solicited at the end of the study indicated that use of the iLs program was beneficial and easy to use, suggesting feasibility and utility of the program. Some suggested that three times per week might be a more realistic expectation in the future. They indicated enjoying the convenience of administering the iLs program at home and going to the clinic only once a week. Specific gains reported by individual parents predominantly related to performance in school.

Implications for School-based Practice

The iLs program is a feasible home program for parents of children with sensory processing impairments and has potential for use in school-based practice. The iLs program appears to address some of the problems of children with sensory processing challenges. This study found changes in the performance of many daily routines essential to participation at home, at school, and in the community. Improvements were noted in functional communication and in education-related abilities such as handwriting, reading comprehension, and schoolwork. Although teachers were not interviewed at the completion of this study, many of the parents reported having pursued this intervention as a means of improving their child's success in school.

This study contributes to evidence-based practices (Thomas & Law, 2013) that are available and required of therapists practicing in the school system (Clark & Chandler, 2013). Since the parent and a research assistant administered the intervention in this study, it suggests a cost effective and time efficient application to school based practice; the iLs program could be administered by a paraprofessional and not require the full time attention of an occupational therapist. A Visual Analog Scale can be used to measure progress and is a potential tool for supporting evidence-based practice. Links between the auditory program and changes in arousal suggest a potential impact on optimizing and enhancing attention skills necessary for learning.

Limitations

This was a single-subject research design with only seven participants, therefore, results are not generalizable to the larger population of children with sensory over-responsivity and auditory processing challenges. One strength of the study is that we looked at functional, behavioral, and emotional goals related to parents' primary concerns for their child and gains were reflected in daily life experiences at home and school. However, since we did not have blind raters of individualized goals, there was potential bias in parental report of change.

Parents implemented the intervention and they were offered a free iLs unit at the completion of the study. Since the intervention was protocolized and music selections were unalterable, we believe this bias was minimized. Fidelity to the intervention was insured through weekly meetings and we assume that parents would not have wanted to keep the iLs unit if their child had not experienced some positive benefit from the program.

This study was designed to examine short-terms effects of the iLs program. Thus we did not follow participants beyond 3 to 4 weeks after completion of the program to determine whether their gains had been maintained. Additionally, fluctuating patterns at the end of treatment could not be interpreted owing to the paucity of data points. Future study designs should incorporate a planned reassessment in 3-, 6-, and 12-month intervals to establish how long progress is sustained.

Finally, future research needs to determine whether the type of physiological changes reported in this study are clinically significant and to further explore the relationship between such physiological measures and behavioral change. This study provided only preliminary evidence that arousal and reactivity change as a result of iLs intervention. These measures have the potential to provide greater insight into the arousal mechanisms that underlie this intervention.

Directions for Future Research

Additional research is indicated to substantiate the benefits of the iLs program Although not administered in a school setting, results of this study reflect gains in academic and nonacademic abilities. Implementation of the iLs program at school may provide an even more convenient alternative to parents. This hypothesis requires further study. An assessment of school function is needed along with the inclusion of standardized measures directly related to educational success. Functional changes should be confirmed by teacher-report measures and teacher observation of a child's abilities in the classroom.

Conclusion

This pilot study provides preliminary and partial support for the effectiveness of the iLs program delivered five times a week for children with sensory over-responsivity and auditory processing problems. The attainment of individualized functional goals was an important outcome of this study. Additionally, physiological changes in arousal and reactivity to sensory challenges were noted following intervention, which can be used for future hypothesis generation. Behavioral and emotional dimensions tapped by the BASC show potential for use in future studies. Overall parents had a positive reaction to participation in the program and expressed satisfaction with their child's progress. Further study of this auditory program is warranted.

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