[CASE STUDY]

The impact of occupational therapy using Ayres Sensory Integration® on a child with cochlear implants: a case study

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ABSTRACT

Introduction: A three-year-old child with bilateral cochlear implants (CIs) was referred to occupational therapy by the cochlear team due to suspected tactile over-reactivity. The child's behaviour fell outside of typical expectations of young children who receive CIs and had a ripple effect on her language and development e.g. removing and hiding her CIs after 45 – 60 min of usage.
Methods: A retrospective, longitudinal, experimental single case study was conducted. Occupational therapy using the Ayres Sensory Integration® approach (OT-SI) was provided to the child for 48 months in a private practice in South Africa. This study aimed to show that the child's sensory perception and regulation improved over time as a result of intervention. Results of the Sensory Integration and Praxis Tests completed at 23 and 42 months after the onset of intervention were compared.
Outcomes: After OT-SI intervention, the child tolerated and enjoyed wearing her CIs during waking hours every day. Test results and her increased participation in occupations confirmed that the child showed significant improvement.
Conclusion: OT-SI made a meaningful difference for this child and should be considered as part of the intervention for children with CIs. The parents and cochlear team were satisfied with the positive outcomes of intervention. The study highlights the potential contribution of the occupational therapist to the cochlear team.

Implication for practice

- This case study provides valuable insights to promote early intervention to support occupational therapists working with young children with cochlear implants.
- Clinical strategies are shared to stimulate professional reasoning and articulate goal setting for a child-directed intervention plan.
- Knowledge is shared to empower occupational therapists to make a valuable contribution to the cochlear team and to fill the gap in available literature.
- The article reflects the value of a support system for parents of children with cochlear implants.
- Fostering continuous communication between team members can create an atmosphere of empathy and recognition of each family's unique journey.

INTRODUCTION

Cochlear implants (CIs) are considered one of the greatest advances in modern medicine. These medical prostheses are used to treat sensorineural deafness and improve quality of life for clients with hearing loss[1]. The benefits of CIs include auditory inclusion, gains in confidence, and increased ability to function in society[1]. A significant improvement in technological advances, earlier implantation and earlier intervention have demonstrated an improvement in paediatric cochlear implant (CI) outcomes[2].

According to Muller and Hagenfeld[3] candidates considered for cochlear implantation have evolved to include children younger than 12 months, children with significant cochlear abnormalities, and children with other disabilities. Considering these expansions, it is crucial to evaluate each case on an individual basis. This evaluation is typically performed by an experienced multidisciplinary cochlear team[4]. Although it is recommended that cochlear teams should consist of otorhinolaryngologists, audiologists, speech therapists, educational specialists, physio- and occupational therapists, psychologists and social workers[3], therapeutic services for children with CI's generally revolve around audiology, and speech and language development[5]. In South Africa, occupational therapists are not typically part of cochlear teams, but can be consulted externally. Financial resources and accessibility to services (pre- and post-implantation) may play a significant role in a child's outcomes, e.g. if a child is able to receive bilateral implants, which in turn has a better prognosis[2].

An unusual case of a three-year-old child with bilateral CIs was identified by the cochlear team based in a metropolitan area in South Africa. The child was referred to private occupational therapy due to the team's concerns around possible tactile defensiveness, recently described as tactile over-reactivity[6] or hyper-reactivity[7]. The team's main concern was that the child was removing and hiding her CIs after 45 – 60 minutes of usage. Therefore, she did not have access to the full range of auditory input and specifically to language for extended periods on a daily basis. Her behaviour was perceived as atypical compared to other children with CIs who could typically wear their devices consistently during waking hours[8].

In addition to removing her CIs, she was also hiding under tables and isolating herself when she felt overwhelmed or overstimulated. These behaviours had a meaningful impact on her overall development, as well as the family's everyday activities and social life. The cochlear team was concerned that the child was not participating and benefitting optimally from learning opportunities, for example due to her limited social participation in the family unit and withdrawal from community or self-care activities. These behaviours could potentially impact her participation in daily occupations and concerns were raised that she could miss the critical window of optimal language development (e.g. developing vocabulary for spoken / expressive language and social skills), and would not learn to interpret the sensation of sound with meaning[9].

Occupational therapists are primarily concerned with a person's occupational performance in a specific context and design individualised occupation-based intervention plans to improve the overall quality of participation in everyday life[10]. Therefore, the treating occupational therapist could address a twofold objective in this case. Firstly, intervention could support this child's occupational participation in her daily life, and secondly intervention would assist the cochlear team with their objectives regarding exposure to sound and the development of language and communication skills.

Ayres Sensory Integration (ASI®) is a neuro-behavioural theory that was originated by Dr Jean Ayres in the 1950's. ASI® is a frame of reference regularly used by occupational therapists when providing intervention to children[11]. Ayres defined sensory integration as the "organization of sensory input for use"[12]. ASI® is adaptable in nature and can be applied across age spans and diagnostic categories[13,14]. A key feature of ASI® theory is the adaptive response that is viewed as the catalyst for change[6]. Adaptive responses are facilitated by neuroplasticity and are elicited by means of active participation during sensory-motor activities[7]. Motor activity, interest in the task and cognitive demands required from the activity also appear to be significant contributors for enhanced neuroplasticity that supports the individual's adaptability[15].

Sensory integration is a developmental process. Accordingly, ASI® intervention is based on the developmental sequence and considers all the sensory systems as important contributors to behaviour and learning. Adequate processing and integration of sensory input is the basis for adaptive behaviour. Intervention starts at the child's current level of sensory-motor functioning and gradually progresses to more complex and higher-level actions and interactions, also referred to as the end products of sensory integration. ASI® is a bottom-up approach that focusses on the lower-level interactions between sensory systems and sensory-motor factors to facilitate higher level organisation of behaviour, growth, and learning[6,16].

Occupational therapists working in the field of ASI® consider an individual's perception of sensory experiences as well as the (often invasive) role of sensory disturbances in everyday life, together with the resulting effect on an individual's emotional well-being and participation in occupations[17]. ASI® utilises specific assessments and interventions that can successfully be applied to a variety of diagnostic groups, including sensory loss such as visual impairment[12–14,16,18,19]. Schaaf and Mailloux[20] stated that numerous studies over more than six decades have shown that there are common patterns associated with sensory integrative dysfunction.

The sensory integration and praxis test (SIPT) is currently considered as one of the best researched and scientifically sound measuring instruments available for detecting developmental problems based on sensory integration function and can be used on children in South Africa[21]. On the basis of SIPT scores, six cluster patterns of sensory integrative dysfunctions have been identified[20]. According to Mailloux et.al.[22], understanding the different patterns of sensory integrative dysfunction allows occupational therapists to be better equipped to design, implement, and study intervention programs to alleviate challenges and, ultimately, to support occupational performance[22] .These patterns include poor sensory perception, somatodyspraxia, vestibular and bilateral integration deficits, visuodyspraxia and difficulty with sensory reactivity. Sensory reactivity can manifest as either hyper- or hypo-reactivity to sensory input[20].

Lane et.al.[7] explain that individuals with sensory hyper-reactivity display an unusually strong fight or flight response in the presence of aversive, and often non-aversive, sensory experiences. Physiological mechanisms associated with hyper-reactivity to sensation include elevated electrodermal activity (a measure of sympathetic activity) and slower habituation in response to repeated sensory events[7]. It has also been hypothesised that difficulties to filter out unnecessary sensory stimuli could be linked to the experience of hyper-reactivity[7].

Schaaf and Mailloux[20] operationalised the concepts of ASI® into a systematic framework called the Data Driven Decision Making model (DDDM) and is designed to guide the therapist's clinical reasoning and decision making. The DDDM is a step-by-step model that directs the use of assessment data to guide intervention, to articulate goals, and to document the outcomes of intervention. As part of this process, proximal and distal outcomes are identified to provide a link between sensory-motor skills and the potential impact on functional performance. Proximal outcomes are described as sensory-motor factors that are targeted in intervention (e.g. poor sensory perception, poverty of movement or impaired praxis). Distal outcomes are described as the areas of participation and function that are noted in goals, and that are expected to change as a result of intervention e.g. functional skills and behaviours. The DDDM consists of a series of eights steps, namely: 1. Identifying the child's strengths and participation challenges; 2. Conducting the comprehensive assessment; 3 Generating a hypothesis; 4. Developing and scaling goals; 5. Identifying outcome measures; 6. Setting the stage for intervention; 7. Conducting the intervention, and 8. Measuring outcomes. Although the DDDM was documented to promote participation for children with autism[20], it was a valuable and adaptable tool to guide the clinical procedures for this child with CIs.

It has been well-documented that children with CIs are at risk for balance and other motor deficits[5]. Koester et al.[23] reported that children with CIs may have sensory integration challenges and explained that their SIPT scores typically reflected the vestibular and proprioceptive bilateral integration and sequencing pattern of sensory integrative dysfunction, particularly relating to vestibular vulnerabilities. In addition to the surgical trauma of inserting the electrode array, it has been hypothesised that, due to the close proximity of the vestibular and cochlear receptors, indirect electrical stimulation of the vestibular nerve may cause damage to the vestibular receptor cells and contribute to vestibular deficits in children with CIs e.g. compromised balance[24]. Figure 1 (page 3) illustrates the proximity of the sense organs of the inner ear, including the cochlea and the vestibular apparatus.

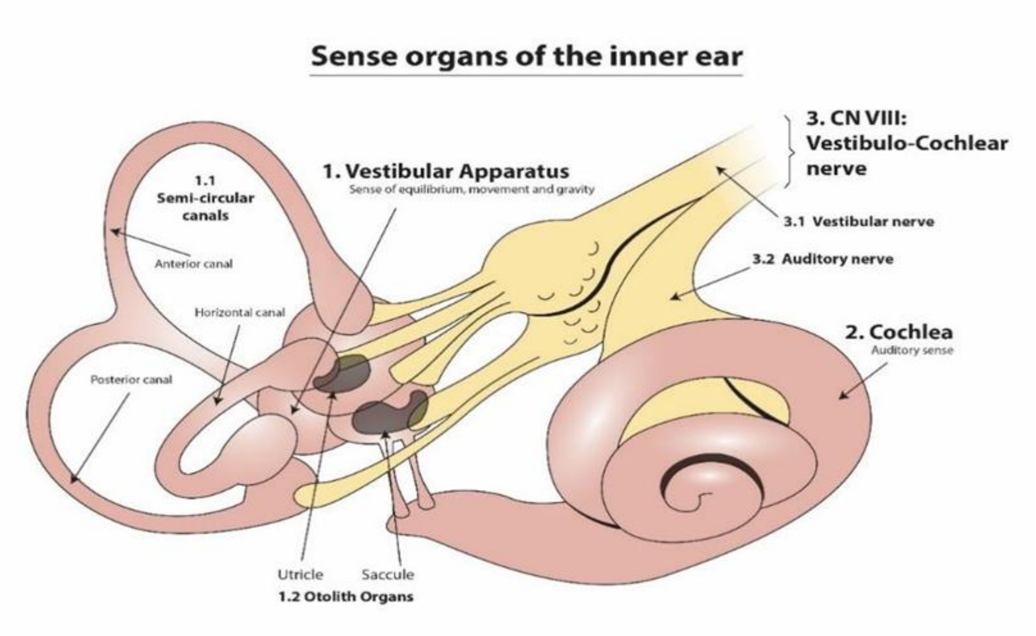


Figure 1: Illustration of the sense organs of the inner ear

The vestibular system is particularly important to the developing child [25] as it facilitates the fundamental relationship between a person and the physical world through gravity, which is always present and cannot be switched off or removed like CIs. When the vestibular system does not function optimally, interpreting other sensory information may be inconsistent and inaccurate, contributing to limited exploration behaviours [26] and compromised gross motor skills [27].

In this case study, the child appeared to experience challenges related to sensory reactivity and perception and it was evident that an in-depth and holistic assessment was needed.

Case description

The child received her first CI at the age of two and a half years. The cochlear team soon identified acceptance difficulties of the newly implanted device. During the course of that year, the child experienced additional issues with her cochlear device (e.g., changing of faulty parts) and she developed granuloma annulare in the area of the magnetic field on her scalp (small, red bumps in a ring pattern on the skin), that may have contributed to irritability. She received her second CI 11 months later, which appeared to magnify her challenges. As a result, her case was discussed at a cochlear conference, and she was subsequently referred to occupational therapy. The referral to occupational therapy to investigate possible sensory integration difficulties was made three months after receiving her second CI.

Intolerance to the CIs and the resulting removal of the devices, accompanied by over-reactive behaviours, negatively impacted her participation in childhood occupations. She experienced challenges in activities of daily living such as dressing, eating and grooming, as well as with family outings and socialization. It was initially impossible to administer a structured standardised assessment, obtain reliable results and pinpoint a single sensory trigger that could explain the child's continued removal of the devices and over-reactive behaviours. Clinical observations during sensory-motor play-based activities, together with collateral information from the parents and cochlear team suggested that the child seemed to experience input from multiple sensory systems more intensely than her peers. The multi-sensory combination of sound via the CIs, together with movement and touch, seemed to culminate in severe sensory over-reactivity. This resulted in her removing the CIs to eliminate the sensory input she could control. Her behaviour was a means to communicate her discomfort when she did not have the language skills to express herself.

Behaviours consistent with tactile over-reactivity included changing her clothes up to eight times per day and having up to three baths daily to help her self-regulate. She could not tolerate anything on her head (e.g., hair clips or hair bands) and was extremely uncomfortable with the feeling of dirty or wet clothes on her body. These behaviours developed only after the CIs were implanted and were not present before. Furthermore, the granuloma annulare localised in the area of her cochlear device, may have contributed further to tactile discomfort. This caused additional irritation to the skin around the device and coil and potentially increased tactile sensitivity, resulting in her removal of the CIs.

Sound was a new experience to the child, and a degree of sensory disorganisation could be expected. However, one could not ignore the impact of the cochlear device, which prompted an electrical signal that represented sound. It is possible that the child experienced a degree of over-reactivity to sound or auditory defensiveness. She presented with some symptoms that are characteristic of auditory over-reactivity, such as difficulty adapting to the CIs, removing, or hiding the CIs, and a loss of appetite when feeling overwhelmed by sounds from her environment. It was clear that it was difficult for the child to effectively filter and process the sound input to respond appropriately to her environment. By regularly removing the devices, she appeared to gain control over external sensory input - she could intentionally avoid the auditory input from the CIs, and/or the tactile discomfort of wearing her CIs.

Regarding her vestibular system, her behaviour seemed to be an overreaction to the situation as her behaviour did not match the intensity and duration of her sensory experiences (over-reaction to gravity related input), e.g., by avoiding movement and withdrawing from activity while wearing her CIs. Her over-reactive behaviours had an impact on her emotional well-being which had to be further investigated. Her behaviour also influenced her family's ability to engage in social and other activities that were important to them (e.g. going to church, the shops, or a party)[16].

In addition to her inability to effectively process multi-sensory input from her environment (external input), the question arose if there could be an internal trigger that contributed to the discomfort and the desire to remove her CIs. Dizziness and post-operative vertigo are typical complaints or complications reported by adults after cochlear implantation. Sound-induced vertigo due to environmental noise may occur in persons with CIs. Tullio's phenomenon[28] has been described as sound-induced vertigo elicited by environmental noise in adults. Sound-induced vertigo seems to be primarily caused by electrical co-stimulation of the saccule as part of the otolith organs in the vestibular system. A possible diagnosis of Tullio's phenomenon could partially explain her adverse response to wearing her CIs due to the passive electrical stimulation the otolith organs were receiving through the CIs, creating a feeling of vertigo without movement.

As viewed in Figure 1 (adjacent), the saccule, together with the utricle, are part of the otolith organs, and is anatomically adjacent to the cochlea, where the electrode of the cochlear apparatus is inserted. The proximity between the cochlea and otolith organs could partially explain her sensory over-reaction to multi-sensory input from her body.

Unfortunately, as a result of her delayed language skills, this child did not have the verbal skills to communicate and compare her pre- and post-operative experiences. She could not verbalise her discomfort and did not have the vocabulary or understanding of the assault on her sensory system to express her experiences verbally. Her behaviour was seemingly the only means of communicating her discomfort. Her increasingly over-reactive behaviours had a significant impact on the family unit and challenged the roles of the parents to provide for their child's emotional, physical and financial needs as well as her younger sibling.

ASI® intervention was selected as an appropriate therapeutic framework to reduce sensory over-reactivity and facilitate adaptation, improve this child's sensory perception, and the development of refined motor skills for optimal participation in childhood occupations. The child's unique and complex clinical picture indicated the need for a specific child-directed intervention.

METHOD

A retrospective, longitudinal, experimental single case study design was selected [29,30]. The first author provided occupational therapy input to the child for 48 months, using ASI® intervention principles according to the requirements of the Fidelity Measure[31]. This single case study aimed to show that the dependent variables (sensory-motor skills) changed over time when the independent variable, ASI® intervention, was implemented. The cause-and-effect relationship between variables was established by comparing the outcomes of the Sensory Integration and Praxis Test (SIPT) completed on two different occasions (23 months and 42 months after onset of intervention). Observations made by the primary author, as well as information from the parents and cochlear team, were also included.

The SIPT identifies three types of validity adherence, i.e., construct validity, criterion-related validity, and content validity, as well as test-retest reliability[32]. The SIPT was shown to have a fairly high test-retest reliability as a diagnostic measurement tool and can be used with children between 4 years and 8 years 11 months[32]. Research indicated that the SIPT is a reliable assessment instrument for South African children [33]. A South African study indicated relative consistency in the patterns of sensory integrative dysfunction compared to children in the United States of America[34]. Van Jaarsveld et al. [21] demonstrated that the SIPT could be used confidently, and the results could be used as a starting point for ASI® intervention. The SIPT was used as a standardised assessment tool to measure changes in the child's underlying sensory perception after a period of intervention, i.e., to indicate if ASI® intervention was effective for this child.

Due to the child's significant challenges and age (three years and six months at the time of the initial referral), conducting a standardised assessment such as the SIPT was not possible. Hence regular video recordings of her OT-SI sessions were made with the parents' permission. A video checklist was designed to score the recorded sessions. This checklist, called the OT-PICS [Occupational Therapy Paediatric Intervention) outcomes for Cochlear Implants using sensory-motor play-based activities checklist] measures small increments of change, recording the child's performance against herself, instead of using norm-based references. The development and scoring of the OT-PICS checklist does not fall within the scope of this article, but can be viewed in Author (2020, removed for blinding purposes). The two SIPT assessments were done after 23 months of intervention (SIPT 1) and again after 42 months of intervention (SIPT 2) when the child's work habits, age and level of participation were more optimal.

The child received individual OT-SI intervention sessions of approximately 45 – 60 min for 48 months (besides holidays and in the instance of illness). The intervention adhered to the structural and process elements of the fidelity requirements of ASI®, meaning that the intervention was true to the underlying ASI® therapeutic principles[31]. Complying to fidelity requirements allowed the researcher to verify the therapeutic strategies used in this case and make the study replicable[35].

Ethical consideration

Ethics approval for this study was obtained from the Faculty of Health Sciences ethics committee at the relevant institution (Ethics reference number 367/2018). The parents provided informed consent, and the child provided assent.

INTERVENTION

During the child's occupational therapy intervention period, she progressed through different developmental stages, as she was able to make adaptive responses and function better in her daily occupations and in increasingly more demanding and complex tasks. The different stages of intervention were therefore divided as follows: (1) Understanding and addressing sensory over-reactivity (initial adaptation and sensory needs); (2) Identifying and improving challenges related to sensory perception (skills-based, open to challenges); (3) Facilitating refined use and participation in childhood occupations as described in the clinical reasoning model of van Jaarsveld[36]. Appropriate therapeutic strategies and principles were selected and applied during the different phases to facilitate her improvement.

Intervention stage 1: Understanding and addressing sensory over-reactivity (initial adaptation and sensory needs)

During this initial phase, the focus was on dealing with her coping behaviours due to her sensory over-reactivity. The parents and cochlear team were looking for possible explanations, and to identify alternative and more appropriate ways of supporting her and helping her to adapt and regulate. The family was cautious about going out to public places and group gatherings to minimise opportunities that would cause stress or sensory overload to the child, which resulted in them becoming isolated from social events they would usually enjoy as a family.

During this stage, it was not possible to conduct a standardised assessment. Besides the child being too young for the SIPT, she struggled with sensory over-reactivity resulting in disorganised behaviour and lack of participation in structured tasks or tasks where she could not control the type or intensity of the sensory input. Age-related sensory-motor play-based activities were used for diagnostic observations to identify her strengths and challenges. She preferred sedentary and visual perceptual games but moved quickly between activities. Although she did not have tantrums or emotional outbursts, it was clear that she avoided certain equipment and challenges and was attempting to find ways of coping with (and at times avoiding) the sensory demands of her environment while wearing the CIs. With the parents' permission, the first author made video recordings to assist with observations and analysis of possible sensory input to match her behaviours with specific events. The cochlear team and parents independently monitored her cochlear usage and adjusted her electrode mapping where and as necessary to create a better user experience.

During OT-SI sessions, adjustments were regularly made e.g., decreasing noise with carpets or pillows, working alone in the occupational therapy room with minimal disruptions and allowing auditory breaks by removing her CIs during movement activities and putting them back on afterwards so that she could first experience the sensory input through her body, before adding the auditory input. This phase was a continuous process of adapting from moment to moment. The first author adapted and adjusted the environment and the type of equipment, provided scaffolding for activities and focussed on being in tune with the child's needs (i.e., to upgrade or downgrade the intensity and dosage of sensory input and complexity of the activities in the moment where necessary to avoid sensory overload). The child was given the opportunity to process movement and sound input separately as stepping stones to promote adaptation and integration of multi-sensory experiences.

Intervention stage 2: Identifying and improving challenges related to sensory perception (activities skills-based, child open to challenges)

After three to six months of OT-SI intervention, everyone understood the child's sensory needs better. The occupational therapist and parents supported and guided her sensory regulation to the point where she was more focused and able to complete activities and other age-related structured tasks. She could integrate sensory input more effectively and her verbal communication skills improved. She could use two or three-word sentences to verbally express herself e.g., "stop, no more" which gave her a sense of control over her environment.

SIPT1 was conducted 23 months after the initial referral. After SIPT1, her intervention focused on improving her sensory perception and sensory-motor skills without going into sensory overload and triggering fight-or-flight responses. The child was able to start attending school during this stage. The family was increasingly able to participate in outings and social events to lead what they described as a more meaningful family life.

Intervention stage 3: Facilitating refined use (of skills) and participation in childhood occupations

During this phase, it was possible to conduct a re-assessment using the SIPT. Nineteen months after SIPT 1, the first author administered the SIPT2.

The focus of the child's intervention shifted to more refined use and integration of skills, as well as improved participation in occupations such as activities of daily living and education.

OUTCOMES

The outcomes of the intervention will be discussed according to the stages of intervention as identified previously.

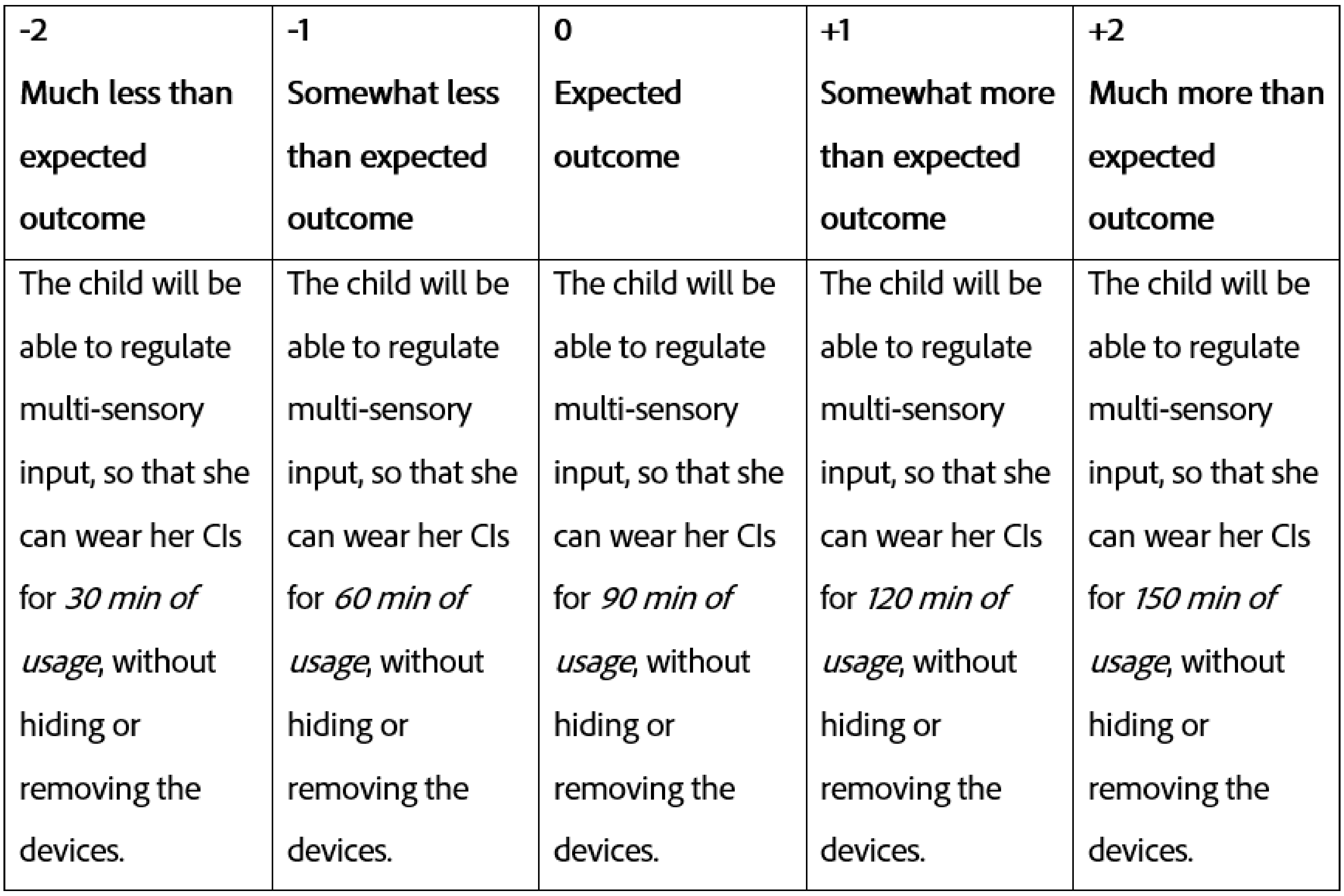
Outcomes of intervention stage 1: Understanding and addressing sensory over-reactivity.

The goals for intervention were set by using goal attainment scaling (GAS), as described by Schaaf et al[20]. The GAS goal pertaining to the breaks supported her awareness and development of self-regulation, which wearing of the CIs (that was the primary goal of intervention) is included in Table I (below).

Table I: GAS goals set during Stage 1 of intervention

Goal 1: Within six months, the child will adapt to multi-sensory experiences and wear her cochlear implants for all waking hours during the day.

Current level: The child is hyper-reactive to sensory input, especially light touch on her head and cannot tolerate wearing hair clips, headbands or her cochlear implants for more than 45 – 60min at a time.



-2 **Much less than expected outcome**	-1 **Somewhat less than expected outcome**	0 **Expected outcome**	+1 **Somewhat more than expected outcome**	+2 **Much more than expected outcome**
The child will be able to regulate multi-sensory input, so that she can wear her CIs for *30 min of usage*, without hiding or removing the devices.	The child will be able to regulate multi-sensory input, so that she can wear her CIs for *60 min of usage*, without hiding or removing the devices.	The child will be able to regulate multi-sensory input, so that she can wear her CIs for *90 min of usage*, without hiding or removing the devices.	The child will be able to regulate multi-sensory input, so that she can wear her CIs for *120 min of usage*, without hiding or removing the devices.	The child will be able to regulate multi-sensory input, so that she can wear her CIs for *150 min of usage*, without hiding or removing the devices.

At the start of intervention, the child was hyper-reactive to multi-sensory input, and coped with the environmental sensory demands by means of removing and hiding her cochlear implant devices after 45 – 60 minutes of usage. However, her parents noticed a change in her behaviour almost immediately after starting with OT-SI. After four intervention sessions, her parents noticed an increase in the use of the CIs. The mother reported that the child wore both her CIs for just over 2 hours and that she was trying her best to communicate. This was more than expected within the timeframe which indicated the child responded positively to the OT-SI (GAS +1). The child could tolerate wearing her CIs with the washing machine switched on for the first time while she was in the house, and she could play outside (running, jumping on the trampoline, riding her scooter bike). She also became aware of background noise like cars and birds. It was only when she tripped when running that she removed the CIs. Her mother felt happy as that was progress for her daughter. The mother ended a text message to the first author with, "Jump with joy!!"

Within the first three to six months of OT-SI, the child's CI usage gradually increased to the point where she wore her CIs approximately 8 hours per day. Her parents felt that was the breakthrough they needed. Her progress exceeded the expectation that was articulated in the initial goal setting, as she responded much quicker than expected (GAS +2). The child was allowed controlled auditory breaks during this time i.e. intentionally removing her CIs without hiding them. These assisted her to communicate her need when she felt overstimulated by multi-sensory input. After a break of about 30 – 60 minutes, she was willing to put the CI devices back on and felt that her sensory needs were met. This sensory strategy supported her ability to adapt to the devices and wear them during all hours of the day.

Outcomes for intervention stage 2: Identifying and improving challenges related to sensory perception

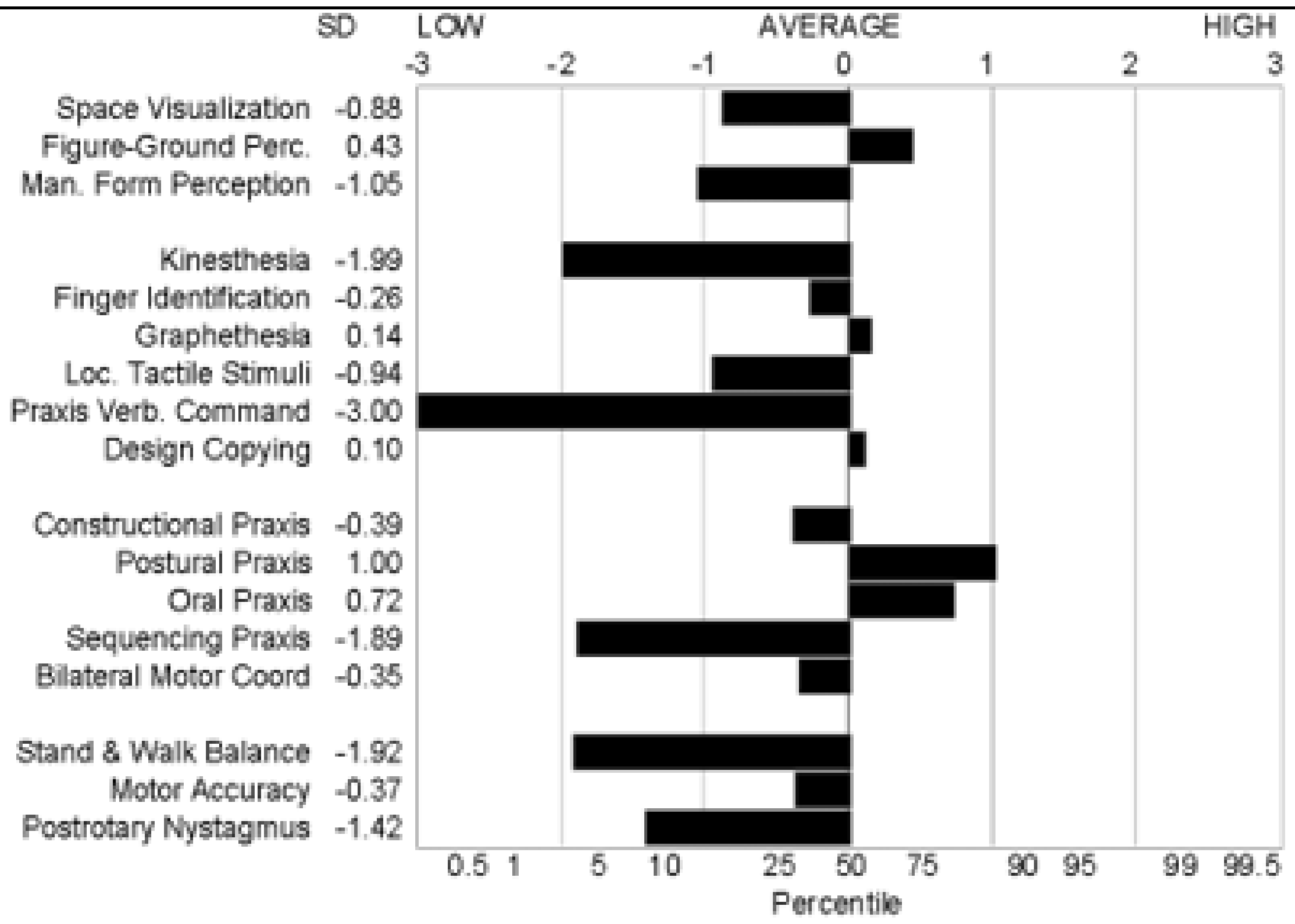
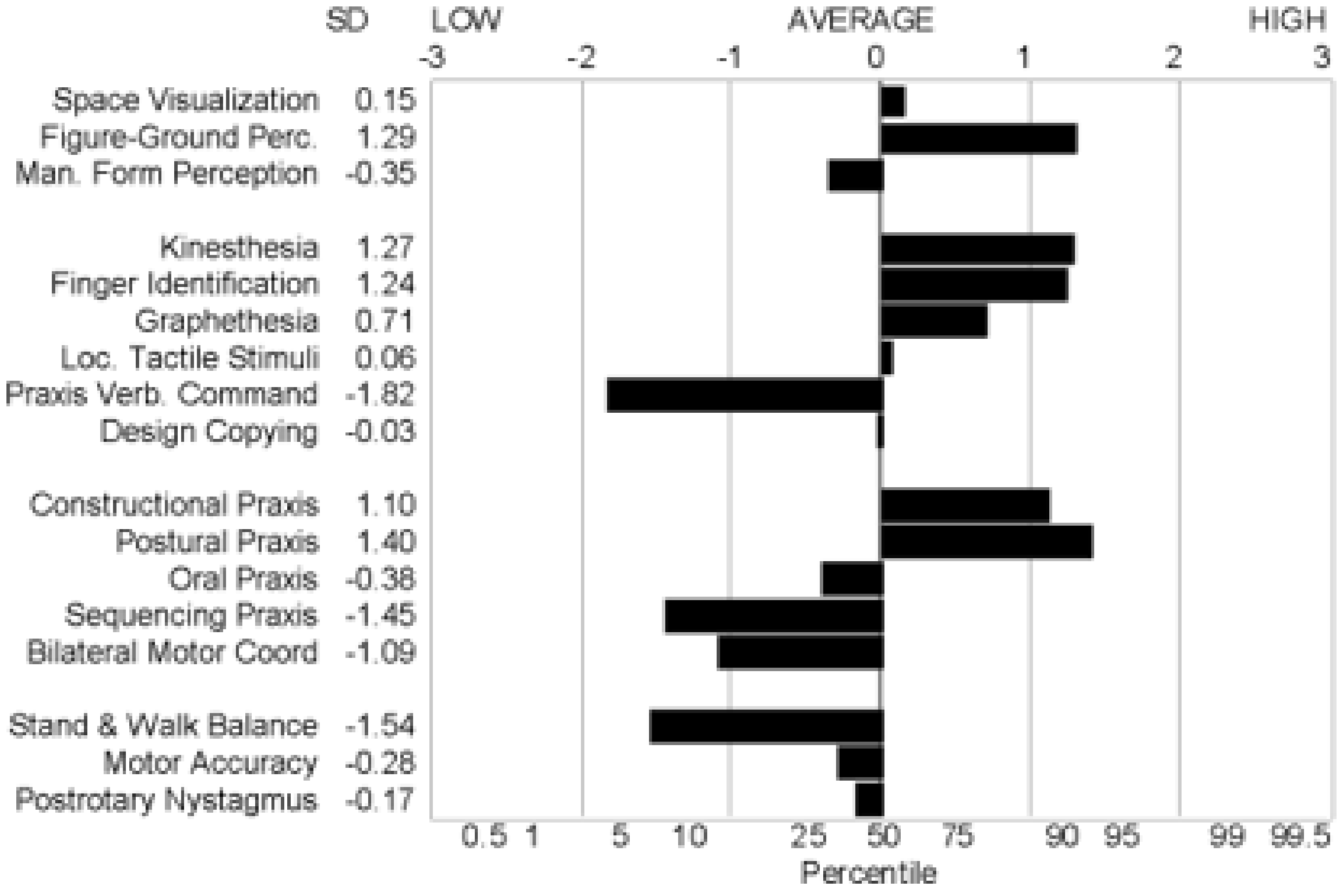
The SIPT 1 was conducted during this stage when the child was 5 years and 4 months old. The scores that were below the norm for her age were Kinesthesia (KIN) (-1.99); Standing Walking Balance (SWB) (-1.92); Sequencing Praxis (SPr) (-1.89); Post Rotary Nystagmus (PRN) (-1.42); and Manual Form Perception (MFP) (-1.05). It could also be expected that she would have difficulty with following verbal instructions, evident in her score for Praxis on Verbal Command (PrVc) (-3.00), which fell in the severely dysfunctional range. The child's SIPT test results are characteristic of the Vestibular and Proprioceptive Bilateral Integration and Sequencing (VPBIS) pattern of sensory integrative dysfunction. These scores associate bilateral integration and sequencing deficits with the vestibular and proprioceptive systems [5,27,32,34].

Outcomes for intervention stage 3: Facilitating refined use and participation in childhood occupations

While the child was only using her CIs for about 45 – 60 minutes at a time in the initial stage, during stage 3 she was enjoying sound to the point where she did not want to remove her CIs. At the end of the four-year intervention period, the child entered a mainstream school where she could benefit from good language and communication models. She could even tolerate hair clips, ponytails, and a cap for sport. Furthermore, her communication and self-esteem improved to such an extent that she could make friends at school. The family became more integrated into their community and could enjoy community activities together.

The SIPT was re-administered after a further 19 months of OT-SI. The SIPT1 and SIPT2 scores are presented in Table II (below). The two sets of results were statistically compared to determine the changes in sensory processing and sensory integrative skills.

Table II: SIPT 1 and SIPT 2 comparison

<table>
<tr><th>Assessment</th><th>Assessment results</th></tr>
<tr><td>SIPT1
(5 years
4 months)</td><td>
</td></tr>
<tr><td>SIPT2
(6 years
11 months)</td><td>
</td></tr>
</table>

Note: The child's first score for Praxis on Verbal Command was SD -3.0 (Raw score: 0/24 correct).
The child's second score for Praxis on Verbal Command was SD -1.82 (Raw score 17/24 correct).

When considering individual tests, seven out of the 17 tests showed an improvement of one standard deviation or more. These tests include Space Visualisation (SV), Kinesthesia (KIN), Finger Identification (FI), Localisation of Tactile Stimuli (LTS), Praxis on Verbal Command (PrVc), Constructional Praxis (CPr) and Post-rotary Nystagmus (PRN). Although the score for Manual Form Perception only showed an improvement of +0.7, the score went from the dysfunctional to the functional range.

Table III (below) contains the descriptive results of the two sets of SIPT scores, summarising the overall combined results, combining all 17 items in each of the SIPT1 and SIPT2 tests:

Table III: Descriptive results of two complete sets of SIPT scores

		SIPT 1	SIPT 2
N	Valid	17	17
	Missing	0	0
Mean		-0.71	0.01
Median		-.39	-.03
Std. Deviation		1.08	1.06
Minimum		-3.00	-1.82
Maximum		1.00	1.40
Percentiles	25	-1.66	-0.74
	50	-0.39	-.03
	75	0.1200	1.17

The paired t-test was used to compare the two sets of SIPT score means[37]. The mean scores of SIPT2 were significantly higher than those obtained in SIPT1. The corresponding p-value ($p = 0.008$), implies that the means of the two sets of scores were significantly different.

The significant difference between the two sets of SIPT scores confirms that the child showed significant improvement in performance and underlying sensory processing skills.

In addition to the improvement observed between the two SIPT assessments, the feedback from the family, the cochlear team, and observations from the video material, confirmed an improvement in the child's overall adaptive behaviour and participation in daily activities.

DISCUSSION

In this section, several aspects will be highlighted to obtain an in-depth understanding of a complex case. Firstly, the case illustrates the potential impact of OT-SI on a child with cochlear implants. ASI® was shown to be an effective therapeutic approach with a useful assessment (SIPT) and intervention principles that could be adapted to the child. Therefore, this study supports the usefulness of ASI® specifically for children with CIs, as suggested by Koester et al.[23]. The findings of this study add to the research support for using the ASI® frame of reference, as it results in positive outcomes for children with various conditions[11,18,38].

This case also highlights the importance of incorporating authentic assessment principles when evaluating children, as suggested by Bagnato et al.[39]. In an authentic assessment, multiple perspectives and multiple techniques are incorporated into an assessment. As illustrated in this case, an authentic assessment takes place on multiple occasions to ensure the stability of the findings[39]. It has been described as best practice in early childhood assessment[40]. In this case qualitative information, including observations during sensory-motor play-based activities, feedback from caregivers, collateral reports, and observations from video recordings, were sufficient to initially guide intervention to address the child's severe sensory over-reactivity towards multi-sensory input. The value of the observational assessment should not be underestimated. The DDDM process supported the gathering of evidence during an authentic assessment, as it provided specific data to guide clinical reasoning, and design a targeted intervention plan for this child.

Although the initial assessment was adequate to start the intervention process, the SIPT was a useful, standardised diagnostic tool[33] to identify the child's pattern of sensory integrative dysfunction. In addition to the diagnostic information it provided, it assisted the first author in explaining the child's behaviour to the parents and the cochlear team. The child's initial (SIPT1) results were consistent with previous research that indicated that children with CIs often display the vestibular and proprioceptive bilateral integration and sequencing (VPBIS) pattern of Sensory Integration dysfunction[5]. Furthermore, this study illustrated the value of GAS and reassessment to quantify the observed improvement[18]. The re-assessment provided quantifiable evidence that could assist in explaining the child's increased occupational performance due to improved sensory perception and organisation as observed by the family and cochlear team.

Regarding the child's challenging behaviour, the case highlights the importance of understanding the root cause of a child's behavioural difficulties, as suggested by Absoud et al.[41]. This promotes compassion and facilitates the identification of supportive strategies, as opposed to focusing on undesired behaviours. Removal of the CIs was the child's way of communicating discomfort due to her sensory integration difficulties, in the absence of adequate expressive language skills. When children do not have the verbal and/or language ability to express themselves, observation of their behaviour becomes exceptionally important. Parents play a valuable role in managing challenging behaviours and should be supported in this process[41,42]. The occupational therapist has an important role in equipping parents with the knowledge and skills to identify possible sensory triggers and to implement sensory regulation strategies before the child reacts.

This case discussion echoes the importance of family-focussed service delivery and implies that not only the child but also the family should be viewed as service users. The DDDM was a useful systematic approach that guided the clinical occupational therapy process[20]. The child's parents were actively involved and participated with goal setting. Although implanting the CIs is initially a medical intervention performed "on" the child, the outcomes of the implants heavily rely on the family's involvement[43]. Due to the time sensitive nature of language and speech development, families may experience intense pressure to follow protocols on CI use after implantation. When a child struggles to conform to the protocol (e.g., by frequently removing their CIs, as in this case), the family may experience distress as they feel unable to meet the team's expectations. Perceived pressure may amplify the parents' anxiety and potentially aggravate the situation (e.g. feeling forced to discipline the child). Compassion, understanding and valuing parents as part of the solution are essential for success of the CI procedure and intervention.

In addition to ASI® knowledge and subsequent insight into the child's sensory challenges, the OT's holistic view of the child as a unique individual functioning within a particular context proved useful for the child, family, and cochlear team. Positive outcomes of CIs rely not only on language and auditory skill development[44], but also on all aspects of child development. Although occupational therapists are not typically included in cochlear teams[45], they bring a novel perspective that may be of great benefit to the child and family[5]. Therefore, the inclusion of an occupational therapist into an extended cochlear team should be considered[3].

CONCLUSION AND FUTURE CONSIDERATIONS

Although the results indicated positive changes in this case, more extensive studies are required to determine the benefit of ASI® for children with CIs in different contexts. It is recommended that future research studies utilise the Evaluation in Ayres Sensory Integration (EASI) to measure progress as it is a more cost-effective tool that covers a wider age range[46]. The Sensory Processing Measure 2 (SPM2) should also be considered to obtain information about the individual's perceived sensory preferences and participation in different environments.

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Author contributions

Kitty Uys and Stefanie Kruger were responsible for the study design. Data collection was performed by Stefanie Kruger. Data analysis and interpretation was performed by Tanita Botha, Stefanie Kruger and Kitty Uys. The manuscript was drafted by Karin van Niekerk, Stefanie Kruger and Kitty Uys, and edited by Karin van Niekerk. The references

were prepared by Karin van Niekerk. All listed authors agreed on the final version of the manuscript.

Conflicts of interest and bias declaration

The authors have no conflict of interest to declare

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