Improving children's auditory and sensory skills: An intervention-based evaluation of the effectiveness of the 'Integrated Listening Systems' (iLS) programme for children with sensory processing difficulties.

by

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TABLE OF CONTENTS

Acknowledgements 6

Abstract 7

Introduction 8

Background and Review of the Literature 9

Sensory processing 9

Auditory Processing 9

Visual Processing 11

Vestibular Processing 11

Sensory integration 13

Sensory processing disorder 13

Sensory processing difficulties in autism, dyslexia and attention deficit disorder 14

Auditory processing difficulties in autism, dyslexia and attention deficit disorder 17

Music- based auditory training 20

History of sound- based therapy 21

Auditory interventions for sensory processing disorders 23

The Tomatis Method 24

Auditory Integration Training 25

The Listening Programme 26

Sensory interventions for sensory processing disorders 27

Sensory Integration Therapy 27

Combined auditory and sensory interventions for sensory processing disorders 28

Therapeutic Listening 29

Supportive Evidence on Therapeutic Listening 29

Integrated Listening Systems 32

Supportive Evidence on Integrated Listening Systems 32

Summary: Current study, Research Aims and Hypotheses 34

Study 1 37

Method 37

Participants 38

Design 39

Measures 40

Sensory Processing Ability: Sensory processing measure (SPM) classroom and home form 41

Auditory Test: Scan 3:C auditory test 42

Reliability of Measures Analyses for Study 1 44

Procedures

iLS Programme Intervention 47

Ethical Considerations 48

Results

Study 1 49

Descriptive Statistics 50

Preliminary Analysis 52

Hearing Tests. Scan 3:C analysis 52

Sensory Processing Measure analysis 53

Study 2 55

Method 56

Participants 56

Design 57

Measures 58

Sensory processing measure: classroom and home form 58

Scan 3:C auditory test 58

Reliability analyses for Study 2 59

Procedures 59

Ethical Considerations 61

Results

Study 2 62

Descriptive Statistics 62

Preliminary Analysis 62

Hearing Tests. Scan 3:C analysis 64

Sensory Processing Measure analysis 65

Discussion 67

Limitations of Study and Recommendations 70

Conclusion 72

References 75

Appendices

Appendix A. *Reliability Study -Cronbach's Alpha for Study 1* 92

Appendix B. *Reliability Study -Cronbach's Alpha for Study 2* 93

Appendix C. *Skewness and Kurtosis for Study 1* 94

Appendix D. *Skewness and Kurtosis for Study 2* 95

Appendix E. *Wilcoxon Test. Study 1.* 96

Appendix F. *Wilcoxon Test. Study 2* 96

Appendix G. *Confirmation of Ethics Compliance* 98

Appendix H. *Consent form for Parents* 99

Appendix I. *Consent form for Teachers* 100

Appendix J. *Consent form for Head teacher* 102

List of Tables

Table 1. *Means and standard deviations for Scan 3:C hearing test and Sensory Processing Measure - Study 1* 51

Table 2. *Means and standard deviations for Scan 3:C hearing test and Sensory Processing Measure - Study 2* 63

Table 3*.* *Participant Demographics- Study 1* 104

Table 4. *Participant Demographics - Study 2* 104

Table 5. *Individual mean scores* 105

Table 6. *Effect size Study 2* 113

List of Figures

Figure 1. *Sensational Kids: Hope and Help for Children with Sensory Processing Disorder* 15

Figure 2. *Intervention Schematic for iLS intervention - Study 1* 46

Figure 3. *Intervention Schematic for iLS intervention - Study 2* 61

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Abstract

Sensory processing difficulties are associated with a number of developmental disorders and can be an important issue to address when supporting children with Special Educational Needs (SEN). Recently, a number of programmes have been developed which claim to improve these skills in children. Yet, evidence for their effectiveness is quite limited. The current study evaluated a manualised intervention for sensory and auditory skills in a primary school with children aged 4 to 11, with sensory processing difficulties. The specific programme used in the intervention was the 'Integrated Listening System (iLS). Children undertook an intense series of 20 x 30 minute sessions over 10 weeks involving musical auditory input and sensory motor activities. The evaluation examined the effectiveness of this programme on a) sensory processing assessed at school and at home and b) auditory processing tested at school, across two related studies. Study 1 evaluated the difference in scores for these abilities before and after treatment compared to scores for these children before and after a comparable (earlier) period of 'non-intervention'. There was a significant improvement in auditory performance in the treatment but no difference in the non-intervention period. In contrast there was no significant change in scores for sensory processing for either the treatment or non-intervention conditions. Study 2 evaluated the pre and post test scores for a group of children (n=4) allocated to the treatment condition, compared to a group of children (n=4) allocated to an independent control condition. Neither the control (n= 4) nor the treatment group (n = 4) showed significant change in scores for auditory skill or sensory processing. Thus, the study provides only limited support for the use of this manualised intervention for children with sensory processing issues in terms of improving auditory skills. Implications for practice and further research are discussed.

Introduction

Auditory and sensory training interventions have become popular to remediate children's deficits in auditory processing and have shown some positive results (De Vries, Beck, Stacey, Winslow, & Meines, 2015). However, these commercially available training programmes can be expensive and time-consuming and there has been a lack of research examining their effectiveness (Sinha, 2006). Moreover, though some studies have recently begun to address this, they often have methodological weaknesses which limit the conclusions that can be made about their effectiveness. Methodological weaknesses are present in many of the current studies (Leong**,** Carter, & Stephenson, 2016). The aim of this research is to explore the effects of a newly developed auditory programme known as Integrated Listening Systems (iLS).

The iLs is a multi-sensory programme, sound-based therapy which claims to improve functioning underpinning sensory (especially auditory) processing and integration for children with sensory processing difficulties. (ILSA, 2015). However, there are few empirical studies to provide statistical evidence for the effectiveness of the iLS intervention and therapists use it in their practices based on positive anecdotal feedback. Therefore, it is important to properly evaluate the effectiveness of the programme in order to evaluate the treatment's usage and possible implementation. The present study focuses on the iLS system which uses the iLS Focus Series sensory motor programme, a protocol using specific classical music selections, which are heard each session. This thesis examined the effectiveness of iLS intervention for children with sensory processing difficulties.

Background and Review of the Literature

Sensory Processing

Sensory processing refers to the way the nervous system receives messages from the senses and turns them into appropriate motor and behavioural responses (Eysenck & Keane, 2013). Sensory processing deals with how the brain processes sensory input from multiple sensory sources. These include the five classic senses of-sight, hearing, touch, smell and taste (Sternberg & Sternberg, 2014). Other existing sensory modalities are the vestibular sense (balance and the sense of movement) and proprioception (the sense of knowing one's position in space) and time (the sense of knowing where one is in time or activities); all parts of the central nervous system need to communicate in order to process the information from the senses (Eysenck & Keane, 2013). The sensory inputs themselves are in different electrical signals, and in different contexts (Vanzetta & Grinvald, 2008). The current study concerns the impact of the iLS system on sensory processing and specifically, the integration of the auditory, visual and vestibular senses within this sensory processing.

Auditory Processing. Auditory Processing is the process of sound entering the ear and travelling to the language area of the brain to be interpreted (Dawes & Bishop, 2009; Sloan, 1991). The listener hears a representation of an acoustic occurrence as it is transformed, coded and recorded by the auditory system and the brain processes this information. (Boatman, 2006; Yalcinkaya, Muluk & Sahin, 2009).

The most apparent of abnormal responses to sound is hypersensitive hearing (Berard, 1993). Hypersensitive individuals over-respond to normal sounds, often perceiving typical environmental sounds as bothersome or too loud (Martin et al., 1984). Some individuals have a reduced response to sound in their environment, even when their hearing is 'normal.' A problem within this process is called an auditory processing disorder. Difficulties can occur despite the presence of normal hearing (de Wit et al., 2016). Auditory processing is how the brain interprets what the ears perceive. With an auditory processing deficit, the ears are able to pick up sounds, words, etc., but the brain is not able to process the sounds properly - the auditory information becomes jumbled up or confused and therefore, misunderstood. Auditory processing disorder (APD) may be defined as deficits in processing and interpreting auditory information, despite normal hearing sensitivity, and not due to higher order language, or cognitive factors such as auditory memory (American Speech-Language-Hearing Association [ASHA], 2005; Dawes and Bishop, 2009; Lovett, 2011). This problem can be more severe when the auditory signals are further affected by distortion, competition, poor acoustic environments, or other reduction in signal clarity, strength, or information content (Rosen, Cohen & Vanniasegram, 2010).

APD can show as problems determining the direction of sounds, difficulty perceiving differences between speech sounds and the sequencing of these sounds into meaningful words, confusing similar sounds such as 'hat' with 'bat', 'there' with where, etc. (DeVore et al., 2016). These difficulties can impact on other aspects of cognitive functioning. For example, children presenting with this condition find verbal instructions difficult to understand and tend to exhibit poor attention (British Society of Audiology, 2011; Moore, 2011). Listening skills are vital in the acquisition of language and learning skills (Jourkouye & Vahdani, 2013). Those suffering from APD may also have problems relating what has been said with its meaning, despite obvious recognition that a word has been said. Background noise, such as the sound of a radio, television or a noisy bar can make it difficult to impossible to understand speech, since spoken words may sound distorted either into irrelevant words or words that do not exist, depending on the severity of the auditory processing disorder (Anderson, 2010).

For a child with these types of issues, an open, noisy classroom can present a challenging acoustic environment and may affect their ability to process information achieve academically. Hearing difficulties have been linked to poor academic achievement (Daud et al., 2009; Sarant, Harris, & Bennet, 2015).

Visual Processing. Visual processing affects how the world is viewed, and the brain will interpret what is seen through this visual processing (Sternberg & Sternberg, 2016). When a person has a deficit in visual processing, it can interfere with learning or interpreting information (Eysenck & Keane, 2013). Visual processing problems tend to make reading extremely difficult. Reading requires a person to derive meaning from symbols. As readers develop their skills, visual processing of individual letters is replaced by the processing of groups of letters, both common strings of letters and whole words (Gunning, 2002; Lovett,1987). Visual processing problems can interfere with this making it difficult to discriminate between related letters, figures or objects (Janarthanan, 2017). Visual processing deficits are distinct to poor vision or a vision impairment. It is not how accurately a person sees, but how this information is processed through the visual cortex that impacts on these abilities (School Psychologist Files, 2019).

Vestibular processing. The vestibular system gives the body a sense of movement and balance and information about where the body is in space and time and is important for maintaining erect human posture (Berthoz, 2000; Wiener-Vacher, 2008). Although humans are not as aware of the sense of balance as they are of the other senses, such as smell, taste, hearing, and sight, the sense of balance is an important and essential sensory process. The sense of balance is necessary for proper motor responses, posture, and eye movements, and requires sensory input from the head and body in its relationship in space. This information is received through the eyes, muscles, joints, skin, and the cerebellum (Kandel, Schwartz, & Jessell, 1991;

Shumway-Cook et al., 2001). The vestibular system provides reference data necessary to control the swinging and dynamic postural balance. It is located in the inner ear and is a system of receptors that provide information about the movement of the head (Northern et al., 1989). A child who suffers from vestibular loss in both ears, will most probably have difficulties with postural control and movement, although other delays in development are also seen. Gross motor functions such as sitting, walking and head control are usually impaired (Kaga, 1999). In extreme cases, after complete vestibular loss, even the smallest head movements may result in gaze instability and postural imbalance, which produce frequent and debilitating episodes of vertigo (Cullen, 2012). More usually, vestibular disturbance results in issues with coordinating and planning motor tasks such as skipping, jumping jacks, catching a ball with two hands, or reaching across the centre of the body (crossing midline), or even coordinating movements of the mouth, resulting in difficulty with speech production (Kranowitz, 1997). When the system is functioning normally, we are usually unaware of a distinct sensation arising from vestibular activity; it is integrated with visual, proprioceptive and other extra-vestibular information resulting in a combined experience and a sense of motion (Kranowitz, 1997).

Vision is closely related to the vestibular system (Cohen, 2013). A balanced and centred body allows the eyes to move smoothly and steadily, focusing and tracking to discriminate between objects in the environment. Difficulty with tasks that require the eyes to move left to right (e.g. reading) or up and down repeatedly (e.g. copying information from the board) may be signs of a disrupted vestibular system. Hearing is also related to this vestibular system. As people with hearing impairments lack adequate sound stimuli, there will be no adequate vestibular stimulation, which leads to awkwardness in coordination and balance disorders (Angeli, 2003; Azevedo et al., 2009; Kaga et al., 2008;). Kovačević and Jachova (2016) also noted that children with hearing impairment very often have problems with walking, dizziness and exhibit clumsiness in performing motor activities, colliding with things.

They have difficulties in acquiring skills typical for their age, such as cycling, skipping and using equipment in children's playgrounds (Formigoni, 1998).

Sensory Integration

Sensory integration involves the different parts of the body receiving sensory information from the environment through the senses and then sending this information up to the brain. SI theory describes information processing as a neurobiological process requiring the detection, assimilation, organisation, interpretation, and use of sensory information that allows an individual to interact adaptively within the environment in daily activities at home, at school, and in other settings (Ayres, 1972b). The theory of SI is grounded on research in neuroscience (Ayres, 1972a; Bundy, Lane, & Murray, 2002; Smith Roley, Blanche, & Schaaf, 2001) and occupational science (Blanche & Parham, 2001; Parham, 2002; Smith Roley & Jacobs, 2008). The brain interprets the information it receives, compares it to other information coming in as well as to information stored in the memory and then the brain uses all of this information to respond to the environment. Therefore, sensory integration is important in all the things that we need to do in daily life, such as getting dressed, eating, socialising and learning. As such, children with sensory processing difficulties often lack adaptive responses and have hypo- and/or hyper-responsivity to sensory stimuli, which can interfere with daily function and participation (Baranek, 2007; Watling & Hauer, 2015).

Sensory Processing Disorder

Sensory processing disorder (SPD) is a neurological disorder that causes difficulties with processing and integrating information from the five senses: vision, auditory, touch, smell and taste, as well as from the sense of movement (vestibular system), and/or the positional sense (proprioception). Disorders of an SPD character are defined as a lack of ability to use information received by the senses in order to efficiently function in everyday life (Adams, Feldman, Huffman, & Loe, 2015). For those with SPD, sensory information is received, but processed atypically and can include a hyper- and/or hypo-sensitivity to certain environmental stimuli (Ayres, 2013). Unlike blindness or deafness, sensory information is received by people with SPD; the difference is that information is processed by the brain in an unusual way that causes distress, discomfort, and confusion. For example, the systems can be overloaded, which can make in turn make performing everyday tasks challenging (Randell, 2019). More specifically, Steigler and Davis (2010) suggest that this over- and under-responsivity to sensory stimuli causes dysregulation and that 'when people are dysregulated, they are less available for educational and social opportunities' (p. 69). Miller (2006) also described the clumsiness, behavioural problems, anxiety, depression, school failure, and other issues which can occur if sensory processing issues are present. Importantly, Ben-Sasson, Carter, and Briggs-Gowen (2010) claim that one in six children experience sensory challenges which result in a disruption to their academic, social and/or emotional development.

Sensory processing difficulties and autism, dyslexia and attention deficit disorder.

Autism spectrum disorder (ASD) is a complex developmental disorder that can lead to dysfunctions in cognition, emotion regulation, and communication skills (American Psychiatric Association, 2013b). Dyslexia, or specific reading disability, is defined as an unexpected difficulty in reading in relation to cognitive ability, education, or professional status (Lyon, Shaywitz, & Shaywitz, 2003; Shaywitz & Shaywitz, 2008). People with dyslexia have problems discriminating sounds within a word or phonemes, a key factor in their reading and spelling difficulties (Snowling, 2013). Attention deficit hyperactivity disorder (ADHD) is a group of behavioural symptoms that include inattentiveness, hyperactivity and impulsiveness. (Asherson, 2004; Polanczyk et al., 2007; Swanson et al., 2009).

Sensory processing difficulties are often seen in individuals with learning and developmental disorders such as autism, and attention deficit hyperactivity disorder (ADHD). Miller, Schoen, Coll, Brett- Green and Reale (2005) investigated the link between sensory processing disorder and autism and found that the disorders were distinct but overlapped (see Figure 1). This study, in which 40 children with high functioning Autism or Aspergers were tested for SPD showed 78% of the children with Autism or Aspergers also had significant signs of SPD.

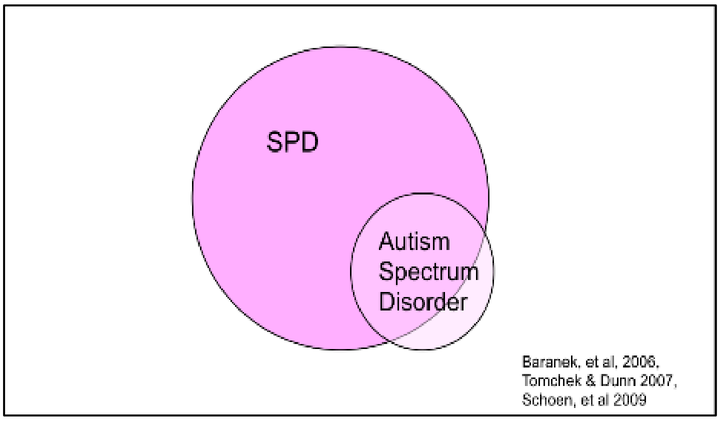

Figure 1. *Sensational Kids: Hope and Help for Children with Sensory Processing Disorder*. (Miller, 2006, p. 249-250)

Sensory processing difficulties have also been implicated in Attention Deficit Disorders and Autism Spectrum Disorder (ASD, Ashburner, Ziviani, and Rodger, 2008; Baker, Lane, Angley, and Young, 2008; Baranek, 2007; Chang et al., 2012). In a systematic review of the literature relating to ADHD, Ghanizadeth (2011) found that evidence sensory processing problems in children with ADHD was not a well -studied area but that sensory processing problems were more common in children with ADHD that in typically developing children. In support of this, recent research by Ben-Sasson, Soto, Heberle, Carter and Briggs-Gowan (2014) highlighted the co-occurrence of sensory over- responsiveness (SOR) - a subtype of SPD - and

ADHD. Borkowska (2017) found many studies indicated that symptoms characteristic of sensory processing disorders (observed in the behaviour of a child) are much more frequently diagnosed within existing diagnostic criteria than in the general population. In the general population the occurrence of SPD is assessed at 5-16%, while in clinical samples, e.g. of autism spectrum disorders (ASD), the symptoms are observed in as many as 90% of children (Owen et al., 2013). It is important to note that most studies examining sensory disorders have been with autism because of the frequency that this occurs with ASD. This has been reflected in the latest version of the DSM-5, where SPD was included in the diagnostic criteria (APA, 2013).

Sensory processing difficulties have also been implicated in dyslexia. Ortiz, Estévez, Muñetón, and Domínguez (2014) concluded that children at risk for dyslexia show visual (and auditory) perceptive deficits for linguistic and non -linguistic stimuli. Other studies have indicated that phonological and visual attention span disorders were linked to simultaneous auditory processing deficits. These studies show that some children with dyslexia exhibited a simultaneous processing disorder in both the visual and the auditory modalities (Lallier, Donnadieu, & Valdois, 2013).

Many schools typically have children with sensory processing disorders which are linked to their difficulties with dyslexia, autism, social communication and ADHD, which involve issues with focus. In looking for an intervention which could address many of these difficulties within the same therapy, it is useful to examine possible underlying sensory processing issues which may run beneath many of the disorders.

A busy classroom can be a difficult place for a child with sensory processing difficulties requiring a concentrated effort emotionally, physically, and cognitively to remain engaged. Occupational therapists can evaluate children and youth and provide interventions to promote self-regulation for those with sensory processing and integration challenges. Pfeiffer et al. (2018) conducted a systematic review of available evidence of cognitive and occupation-based interventions and found improvements in self-regulation in children and youth with sensory processing and integration challenges.

Auditory processing difficulties in autism, dyslexia and attention deficit disorder.

Much research has been undertaken to provide evidence that specific auditory processing deficits within the range of sensory processing issues, are related to language and academic difficulties (Chermak, Silva, Nye, Hasbrouck, & Musiek, 2007; Dawes & Bishop, 2009; Wallach, 2011; Whitton, 2010). As discussed earlier, auditory processing disorder (APD) is understood to be a deficit in the ability to process and interpret auditory information, despite normal hearing sensitivity and not due to higher order language, or cognitive factors such as auditory memory (American Speech Language-Hearing Association [ASHA], 2005; Dawes & Bishop, 2009; Jerger & Musiek, 2000; Lovett, 2011). Researchers have suggested that although auditory processing difficulties are not linguistic, they have a negative impact on language development (Dawes & Bishop, 2009; Sloan, 1991).

Children with autism have been noted as having abnormal responses to sound as one of a number of sensory or perceptual problems. A number of studies have reported evidence for diminished low level auditory discrimination abilities across a range of auditory parameters in ASD (Dabbous, 2012; Foss- Feig et al., 2017, Kargas, López, Reddy, & Morris, 2015,). Moreover, hypersensitive hearing is often apparent. This is defined as 'consistently exaggerated or inappropriate responses or complaints of uncomfortable loudness to sounds that are neither intrinsically threatening nor uncomfortably loud to a typical person' (Klein, Armstrong, Greer, & Brown, 1990). Unusual sensory sensitivities have been found generally in autism but in terms of the auditory modality, hyper - acuity has been found to be the significant sensitivity (Talay-Ongan & Wood, 2000).

Auditory sensory deficits have also been found in children with dyslexia where a phonological deficit has been measured and this aural impairment linked to visual problems. Furthermore, neuronal responses underlying some aspects of auditory sensory processing may be impaired in dyslexia (Stefanics et al., 2011). Basic auditory processing deficits have also been found in some dyslexic children of dynamic and speech prosody- related sound features, (Hamalainen, Rupp, Soltesz, Szucs, & Goswami, 2012). Ortiz, Estévez, Muñetón, and Domínguez (2014) studied reading abilities in pre-school children and results showed that children at risk for dyslexia showed auditory (and visual) perceptive deficits for linguistic and non-linguistic stimuli. These auditory and visual and perceptive deficits were considered to support a theory of temporal processing deficit in which the processing of the temporal properties of stimuli (order, duration, relative timing, and rhythm) was impaired. It has been estimated that 30-50% of individuals with dyslexia are affected by auditory problems (Serrallach et al., 2016).

Auditory difficulties have also been implicated in children with ADHD. Abnormalities were shown in these children's ability to process auditory conflicts and therefore cognitive control. Children with ADHD have also been shown to be less able to evaluate incongruent stimuli (Van Mourik, Sergeant, Heslenfeld, Konig, & Oosterlaan, 2011). Children with ADHD can have difficulty selectively attending to competing channels of information- as shown by a virtual absence of an electrophysiological index of selective attention. Deficits in auditory selective attention in children with ADHD may be caused by reduced information early in the processing stream. A poor quality auditory signal might have effects on later discrimination especially in the face of a complex auditory environment (Gomes et al., 2011). A classroom of other children would therefore potentially present auditory challenges for a child with ADHD. It is estimated that ADHD children often meet the criteria for CAPD (central auditory processing disorders), (Serrallach et al., 2016). In light of findings such as these, it has been argued that ADHD involves not only problems of inattention, hyperactivity, impulsivity but also a core deficit of auditory, visual and motor timing (Serrallach et al., 2016).

The sensory issues that appear to be most affected in children with ADHD are vestibular, which has been associated with attentional difficulties (Shum and Pang, 2009), proprioceptive (Jung, Woo, Kang, Choi, & Kim, 2014), and tactile processing (Parush, Sohmer, Steinberg, & Kaitz, 2007). Earlier research had considered that vestibular and proprioceptive problems in children with ADHD may be connected to difficulties in visual processing (Shum & Pang, 2009; Jung et al., 2014). In support of this, and noted above, deficits in visual timing were observed by Serrallach in 2016.

As the research to date illustrates, sensory processing disorders are present in many cases of children with conditions of autism, dyslexia and ADHD. The current study uses sensory processing disorder as an overarching construct between these conditions and as such, all children taking part in the study had sensory processing difficulties (as confirmed by their score on a sensory processing screening measure). All children were on the schools SEND (Special Educational Needs and Disability) register and exhibited academic and/or behavioural issues within their classes. The study specifically aimed to evaluate whether a tailored, manualised programme, the iLS, would be effective in improving sensory processing in these children, identified for having processing difficulties.

In particular, the research above indicates that auditory problems may also be present in these sensory disorders. The iLS system claims to integrate the auditory, visual and vestibular systems within the sensory processing system, resulting in improvements in behaviour and learning. If effective, this intervention has relevance for many children experiencing sensory processing issues within the classroom.

This current study uses an auditory pre and post -test design to measure any improvements after the intervention. As such, this intervention tests the idea that auditory improvements may be causal in improvements in sensory processing.

Music- based Auditory Training

Research that supports the underlying theory of music-based auditory training programmes comes from neuroscientific research suggesting that musical experience is associated with enhanced brain neuroplasticity, and that this is related to years of music training (Kraus & Chandrasekaran, 2010; Strait, Parbery-Clark, Hittner, & Kraus, 2012). Neuroscientific research has shown that in response to pitch changes during speech, musicians show heightened auditory sensitivity in the cortex and brainstem compared to their non-musician counterparts (Kraus & Chandrasekaran, 2010). Processing of pitch during speech is important for recognising the identity, emotion, and intention of the speaker (Kraus & Chandrasekaran, 2010). Strait et al., (2012) found that musically trained children showed faster auditory brainstem response and decreased response delays. Perception and subcortical processing of speech in noise and related cognitive abilities were assessed in musician and non-musician children that were matched for a variety of overarching factors. Outcomes showed that musicians' advantages for processing speech in noise especially strong during the early developmental years. Importantly, they proposed that musicians' perceptual and neural enhancements were improved by strengthened cognitive abilities with training. This was shown by correlations between auditory working memory and attention and auditory brainstem response properties.

These results are relevant to professionals involved in the remediation of language-based learning deficits, which are often characterised by poor speech perception in noise (Strait et al., 2012). Musical training develops an ability to associate slight acoustic discrepancies with behavioural significance. The findings of Strait et al. (2012) suggest development of the primary auditory cortex can result in a change in subcortical response properties, when combined with behavioural reward. To further support this theory, a study by Strait, Parbery-Clark, O'Connell, and Kraus (2013) found that musically trained children performed better on auditory working memory and auditory attention tasks, but not in visual memory or visual attention, relative to their non-musician counterparts. This evidence supports the idea that auditory abilities can be improved, which is clearly important for therapeutic approaches aiming to use sound to improve processing generally.

History of Sound-Based Therapy

The auditory system may be a method to assist organisation of the nervous system (Frick, 2000). There are direct connections from the auditory system to the subcortical sensorimotor processing centres and other processing centres in the brain (Frick & Young, 2009). As discussed earlier, underlying auditory issues may be implicated in many sensory processing disorders and the use of processed musical selections interventions been shown to have a therapeutic value in these sensory disorders, (Labbé, Schmidt, Babin, & Pharr, 2007). Consequently, new interventions using music to improve auditory and sensory processing problems have been developed over the last few years and many occupational therapists, speech therapists and psychologists are now including music as therapy (Accordino, Comer, & Heller, 2007; Barrera, Rykov, & Doyle, 2002; Hochreutener, 2016). De Vries, et al (2015) undertook a systematic review of sound therapies and found they supported enhanced awareness, improvement in interpersonal skills, enhanced body awareness, self- care and reduced anxiety.

In spite of the evidence supporting the beneficial effects of listening to music (Lai & Good, 2005) there is controversy regarding the effects of therapeutic auditory programmes that use acoustically modified music, and this will be examined. These music-based auditory training programmes suffer from a research-practice gap and lack of peer reviewed published studies and are unable to support the theoretical basis of many of the claims of the programmes. In some cases, there is a lack of consistency in the definition of auditory processing, and an absence of consistent diagnostic criteria used in selecting the sample. Several other issues with the current research are also apparent: insufficient sample sizes, the lack of a control group, and limited measures of auditory processing specifically. A further major limitation of research to date in this area is that rather than testing auditory processing abilities directly, many studies just test learning and behavioural outcomes, assuming auditory processing abilities have improved in the intermediary. As originally noted by Miller (2003), the absence of rigorous effectiveness data means the cost-to- benefit ratio of the sensory processing intervention can be frequently questioned as the cost of these therapies to society can be considerable. Pfeiffer et al (2011) also stated that available research was limited in its generalisability because of design flaws and weak or ineffective outcome measures that produced mixed results.

Miller referred to 'The gold standard' for outcome studies in terms of how well they meet the following criteria: (1) They identify a homogeneous sample, likely a combination of physiological and behavioural measures. (2) They use a manualised protocol for intervention to ensure fidelity to treatment measures. If several research assistants were used, there needed to be a standardisation of the treatment which was being offered to clients if generalised results were to be concluded. (3) Outcome measures should be sensitive enough to detect changes over the specified treatment duration and which targeted meaningful changes. (4) There should be adequate statistical power to detect group differences (Miller, 2003).

These have been issues in the past with published research studies. Miller (2007) concluded that no study evaluating the outcome of OT-SI (Occupational Therapy using Sensory Integration Approach) had met all four criteria; and few had met even one criterion.

Her conclusion was that rigorous evidence supporting or denying the effectiveness of this approach did not exist. Similarly, in terms of autistic children, there are many different treatments and interventions available today, but very little evidence or guidance for parents as to which may be more effective for their child. Empirically conducted studies of the efficacy of various treatments for autism are limited, which leaves parents with little evidence on which to base their treatment decisions (Bowker, D'Angelo, Hicks, & Wells, 2011).

This current study aimed to provide evidence for the efficacy of auditory interventions by empirically testing a current programme of listening therapy and investigated its effectiveness on improving both auditory processing specifically and also sensory integration more generally. The study aimed to adhere to the ‘gold standard’ identified by Miller (2007) by identifying a homogeneous sample. All participants were of primary school age and had sensory processing issues indicated by test scores on the Sensory Processing Measure (SPM) which measured children's sensory processing difficulties at school and at home (Parham, Ecker, Kuhaneck, Henry and Glennon, 2007). The study also used a manualised protocol for intervention to ensure fidelity to treatment measures (the iLS system has a comprehensive manual and sequential programmes). Also, it included outcome measures which were sensitive enough to detect changes over the specified treatment duration and which targeted meaningful changes. The Scan-3: C test was used to detect auditory processing disorders in children (Keith, 2009) and Sensory Processing Measure Questionnaire.

Auditory interventions for sensory processing disorders

As discussed, processed musical selections have been shown to be beneficial in addressing the auditory issues which may underlie many sensory processing disorders (Labbé, Schmidt, Babin, & Pharr, 2007) and these electronically-altered musical interventions have developed over the years.

The Tomatis Method. Many of these sound and music -based therapies originate from the early theories of Dr. Alfred Tomatis. He was an otolaryngologist in the 1950s and developed new ways of treating atypical behaviours with sound. He regarded the ear as a significant sensory apparatus and particularly emphasised the vital role played by the inner ear and its cochlear structures with relationship to the overall organisation of the nervous system (Frick, 2000). Tomatis considered that the voice can only produce what the ear can hear (Frick, 2000). Many modern sound-based therapy programmes, including those based on the work of Tomatis, have added evidence to support various methods of treating the nervous system. In addition to Integrated Listening Systems- the focus of this study - current programmes also include Therapeutic Listening®, Auditory Integration Training and The Listening Programme (Frick, 2000).

Tomatis developed the use of electronically-altered music and developed the concept of 'listening therapy', which involves listening to program exercises and toning tiny muscles in the ear, helping to build stronger multi-sensory pathways in the brain, improving its ability to process sound and enhance communication and cognitive abilities (Stutt, 1983). Studies on the 'Tomatis' method had mixed results. Neysmith -Roy (2001) found that out of six boys with severe autism, three boys experienced major improvements in behaviour, one boy was no longer considered to be autistic and two more were re-categorised as mildly autistic (the study was carried out by research assistants). Ruben (2004) also reported a complete recovery for a study of a child with autism. Davis (2005) evaluated the effect of 60 hours Tomatis training on eleven ADD/ ADHD children and reported that all parents saw some improvements as a result of the Tomatis intervention.

However, for a study of 32 children with learning development issues, Kershner, Cummings, Clarke, Hadfield, and Kershner (1990) found no differences in achievement gains at one-year follow-up and also backed this up with a further two years evaluation which reached the same conclusions. Moreover, Kershner et al. (1990) criticised the fact that many of these types of therapeutic programmes had not been tested under controlled conditions.

Gilmor (1999) carried out a meta -analysis of Tomatis styled interventions and found there was supporting evidence of improvement in the children who received intervention. Although the studies all had small sample sizes, the effect overall (across all studies) was supportive of evidence for improvements. However, they noted clear problems with randomisation and lack of control groups. More recent studies continue to show conflicting evidence however. For example, whilst Corbett et al. (2008) found no benefits in a group of eleven children, Gerritsen (2010) used the dataset from the Corbett et al. (2008) study and analysed the participants at the individual level as separate case studies. There were significant improvements following intervention for individual participants, but these results should not be generalised to the wider population.

Auditory Integration Training. In the early 1960s, Berard, who worked with Tomatis, then further developed a method of sound treatment, Auditory Integration Training (AIT), which was based on some of the Tomatis principles (Rimland and Edelson, 1994). AIT uses electronically enhanced popular or classical music that distorts or modulates sound frequencies at random intervals for random periods. AIT is typically used to correct hypersensitive or distorted hearing. Research on AIT has also produced mixed results. Although several studies suggested limited benefits (Edelson et al., 1999; Rimland & Edelson, 1994, 1995) these studies also had important methodological weaknesses. Moreover, Gillberg, Johansson, Steffenburg, and Berlin (1997) and Mudford (2000), found no differences in children's behaviour, cognitive functioning, or adaptive functioning. These findings suggest that evidence for the effectiveness of AIT has not been demonstrated. Other negative opinions of auditory interventions have been published by organisations such as the American Academy of Pediatrics, the American Academy of Audiology and the National Research Council. However, a more recent study into AIT by Al-Ayadhi, Al-Drees, and Al-Arfaj (2013) did show positive results in children with ASD including improved hearing acuity, reduction in sound sensitivity, improved visual tracking, and improved mood and calm (Al-Ayadhi, Al-Drees, & Al-Arfaj, 2013).

The Listening Programme. According to Advanced Brain Technologies (ABT, 2013), TLP uses psycho-acoustically modified classical music targeting certain frequency ranges that claim to impact functional capabilities including sensory processing, balance, learning, language, play and executive function. (Doman & Lawrence, 2003; The Listening Program, 2014). Gee, et al. (2014) conducted a single-subject case-controlled design, implementing The Listening Program® with a 7-year-old child diagnosed with autism spectrum disorder who demonstrated auditory sensory over-responsivity (SOR) in order to observe the impact on sensory processing after TLP intervention. The results showed that there was a change in measures (Gee, et al., 2014). Measures included the SenSOR scales, the auditory defensiveness scale in the Sensory Processing Measure, and the overall total score from the Sensory Processing Measure. The SenSOR scales rate the over-responsiveness of the child to tactile, vestibular, visual, auditory, proprioceptive, gustatory, and olfactory stimuli (Gee, et al., 2014). There was a reduction in auditory defensive behaviours, such as covering the ears, as well as greater ability to tolerate stimuli and a decrease in sensory processing difficulties (Gee, et al., 2014).

In summary, purely music based auditory interventions have been shown to be effective in many cases, but not all. There remain issues with the design and in most studies, in the interventions and outcome measures used. The current study aims to address some of these problems using specific outcome measures and a control group.

Sensory Interventions for sensory processing disorders

Sensory interventions have been variously defined and refer to widely differing practices. These interventions arise from different conceptualisations about sensory integration and sensory processing as neurological and physiological functions that influence behaviour (Case- Smith, Weaver and Fristad, 2014). Research studies generally define sensory integration therapies as clinic-based interventions that use sensory-rich, child-directed activities to improve a child's adaptive responses to sensory experiences. Sensory-based interventions are characterised as classroom-based interventions that use single-sensory strategies, for example, weighted vests or therapy balls, to influence a child's state of arousal (Case- Smith, Weaver and Fristad, 2014).

Sensory Integration Therapy. Sensory integration therapy (SIT) is one such form of therapy, and it is generally offered by specially trained occupational therapists. It involves specific sensory activities to help a child appropriately respond to light, sound, touch, smells, and other input. Intervention may include swinging, brushing, playing in a ball pit and other activities. Positive effects of SIT on child's performance have been reported by Case-Smith, Weaver and Fristad (2014). In addition, a review of twenty -seven studies on children with sensory processing and integration problems by May-Benson and Koomar (2010) showed that SIT may positively affect motor skills, socialisation, attention, behaviour control, reading skills, participation in game activities, and the achievement of personal goals.

However, Leong, Carter, and Stephenson (2015) conducted a subsequent analysis on seventeen SIT studies and concluded that many methodological weaknesses existed in all the studies and as such there was little robust evidence that SIT was an effective intervention for any diagnostic group. A main weakness in many of the studies was again, a lack of experimental control, lack of explicit criteria for sensory processing disorder, absence of test criteria for selecting participants and poor documentation of the features of intervention. The current study seeks to address these issues by having a control group and describing sensory processing disorder criteria. In addition, the participants were initially identified by the teacher and SEND co-ordinator, but further tested on the SPM scale. Participants who performed poorly in the sensory areas and achieved atypical scores on the SPM scale, were included in the study, thus ensuring the criteria for a homogenous sample was met. Additionally, the features are clearly described and follow a manualised protocol.

Other sensory based interventions (characterised as classroom-based interventions that use single-sensory strategies, for example, weighted vests or therapy balls, to influence a child's state of arousal) have not generally been found to be effective (Case-Smith et al., 2014). This current classroom-based study chose not to investigate the single-sensory strategies more typical for this environment, but rather to use a sensory-rich, child-directed intervention. Programmes such as these are more usually carried out as a clinic- based therapy (Case-Smith et al., 2014).

Combined auditory and sensory interventions for sensory processing disorders

As previous studies have found clear evidence for both auditory and sensory based interventions, a combined approach has been taken by some occupational therapists and researchers. Therapeutic listening has been used as an addition to their interventions, particularly when applying a sensory integration approach (Frick & Hacker, 2001). The sound stimulation appears to calm and organise the child, in preparation for involvement in purposeful activity (Bettison, 1996; Rimland & Edelson, 1995). Ayres (1972, 1979) suggested that auditory input contributes to arousal, self-regulation, and emotions.

Therapeutic Listening®. Based on developmental and neurological principles, Therapeutic Listening® (TL) is a sound-based intervention that possesses implications for optimising sensorimotor function (Frick & Young, 2009). The intervention aims to integrate the auditory and vestibular systems together. TL may affect arousal, sensory modulation, and praxis, but has also been shown to produce positive outcomes in terms of focused attention and sensory motor disorders (Vital Links, 2015). It utilises the role played by the auditory system in receiving sounds and adapting to sensations in order to enhance occupational performance. The auditory system's connection to other parts of the brain allows sound to serve as access to the nervous system (Frick & Young, 2009). In this therapy, physical skills such as attention, sensory integration, social skills, communication, balance and navigation space are learned, whilst listening to specialised music on headphones. The headphone music has been 'filtered' or modified in order to expose the nervous system to 'low sounds' (below 1,000Hz, related to vestibular and postural functions), 'mid -range sounds'(1,000 - 4,000Hz, related to key speech sounds), and 'high sounds' (> 4,000Hz, related to attention discrimination and emotional subtleties) at various times throughout the music track. Additionally, the music has been specially crafted or selected based on the type and the number of instruments used (percussion, bass, stringed instruments all affect the nervous system differently). Music selections range from nursery songs to nature sound to classical music and pop songs. In a Therapeutic Listening session exercise balls, swings, toys, gymnastics pads and ladders are utilised in order to engage the client (usually a child) in active play while listening to the music CDs.

Supportive Evidence on Therapeutic Listening. Clinical findings have demonstrated positive changes in functioning for individuals across a wide range of diagnoses and disorders. Hall and Case-Smith (2007) studied the effects of a sensory diet and TL on children with SPD and visual-motor delays. The study included 10 children aged five-eleven years who had major sensory processing and/or visual motor integration delays (Hall & Case-Smith, 2007).

Exclusion criteria included children with moderate to severe intellectual disability, Downs syndrome, severe autism, and other disorders or delays. The children received four weeks of a sensory diet and eight weeks of TL. This involved two therapeutic listening treatment sessions per day for 8 weeks. The children and their parents then completed four assessments: the Sensory Profile, the Draw-A-Person (DAP) test, the Beery-Buktenica Developmental Test of Visual Motor Integration (Beery VMI), and the Evaluation Tool of Children's Handwriting (ETCH) (Hall & Case-Smith, 2007). Results showed that participation in the TL programme combined with a sensory diet resulted in a significant improvement in children's behaviour (Hall & Case-Smith, 2007). Visual motor skills also showed significant improvements (Hall & Case-Smith, 2007). Additionally, improved attention, sleeping patterns, and consistency in following directions as reported by parents occurred after the intervention programme (Hall & Case-Smith, 2007).

Bazyk, Cimino, Hayes, Goodman, and Farrell (2010) studied the effects of TL on enhancing school performance in pre-schoolers with developmental disabilities. A one-group, pre-test, post-test design was used to measure developmental outcomes in 15 pre-schoolers receiving Therapeutic Listening in addition to their typical therapy services. Children were three-six years old, and listened to TL for twenty minutes twice a day during periods of typical classroom routine. The duration of the intervention varied from six weeks to five months, depending on both the child's needs and the therapist's clinical opinion (Bazyk, et al., 2010). Six assessments measuring fine-motor, visual-motor, social, language, and sensory processing were used. Results showed a statistically significant improvement in all areas as reported on the parent and teacher assessments forms (Bazyk, et al., 2010). However, although research to date for TL does supports its use, there has been inconsistency in the variety of assessments and measures used across all the studies.

Recently, Preto, Malloy and Luong (2017) aimed to both address this inconsistency of use of assessment amongst therapists and to ascertain the effectiveness of Therapeutic Listening Quickshifts (TL-Q), by aiming to standardise the collection of data between therapists using TL-Q. They used Canadian Occupational Measure (COPM) for personal goals, Clinical Observations of Motor and Postural Skills (COMPS), Sensory Processing Measure (SPM), Beery Bukentica Developmental Test of Visual Motor Integration for visual skills, together with therapists' notes and qualitative parent journals to identify changes. The study conducted was a pre-test, post-test prospective case study design to examine the effects of an 8-weeks clinic-based TL-Q intervention on (1) self-regulation and arousal, (2) activities of daily living (ADLs), (3) social interaction, and (4) sensorimotor skills. The intervention consisted of a 15-minute TL-Q session administered twice daily, seven days a week for a total of eight weeks. Five children were included between the ages of 4 and 14 who had been referred to occupational therapy.

Results were mixed but did demonstrate an upward trend toward improved performance Preto, Malloy and Luong (2017). They argue that this supported the use of TL-Q as part of an overall sensory integrative approach to improve function and with possible benefits in (1) self-regulation and arousal, (2) Activities of Daily Living (ADLs), (3) social interaction and (4) sensory motor skills. In particular, there were some significant changes on performance within part of the SPM (Sensory Processing Measure) subtests which supported the use of this assessment. However, there was discussion about the limitations of the inability to closely monitor the implementation procedures completed at home by the parents. This created potential room for error, especially if there were inconsistencies in which parent completed the pre-test and post-test. In addition, the school holidays caused disruption to the intervention schedule taking place at home. Importantly, the TL-Q was carried at the same time as occupational therapy, possibly confounding the effects of both. Future recommendations included conduction of study in a single, consistent setting such that the researcher can control the consistency and accuracy of the therapeutic programme (Preto, Malloy, & Luong, 2017). Following this, the current study confined the intervention to the school setting during the school term and utilised a single researcher for the whole of the programme, ensuring consistency of delivery.

Tashjian, Hair and Taasan (2018) also demonstrated the benefits of using the TL-Q as an intervention within a sensory integration framework for addressing personal, developmental, sensory and motor goals for children. They used a mixed methods design and 23 children aged between 3-12, completed twelve weeks of the TL-Q. They received 30-minutes twice daily music session with high-quality, specialised headphones. The SPM did suggest overall improvements, but these did not reach significance. Importantly, though, the study did produce a standardised protocol for producing consistent data. It included the use of six tests - Canadian Occupational Measure (COPM) for personal goals, Sensory Processing Measure (SPM), Beery Bukentica Developmental Test of Visual Motor Integration for visual skills, Peabody's Development of Motor Skills (PDMS), a Clinical Observation assessments and Parent journals. It was acknowledged that a major limitation of the study was a lack of a control group to separate the effects of TL-Q intervention from direct occupational therapy input (Tashjian et al., 2018). It was recommended that further studies should use a randomised-control design in addition to completing the trial during the school year (Tashjian et al., 2018). This study has built on these recommendations and these will be discussed later in the design section.

Integrated Listening Systems. The iLS system is built on the research of Tomatis and the idea that the ear plays a significant role in sensory processing and overall organisation of the nervous system (Frick & Hacker, 2001). It considers that it is the therapeutic listening combined with a sensory diet which is effective in improving behaviours related to sensory processing in children with SPD and visual motor impairments. (O’Brien-Minson, 2014).

The iLS system claims to improve more than just auditory processing but also global brain functioning and language and cognitive processes (ILSA, 2015). This multi -sensory method aims to be more effective than sound alone methods (previously discussed). It is a programme which combines a customisable auditory programme with visual, vestibular and movement activities (O’Brien-Minson, 2014). The method is based on the premise that specific, simultaneous and repeated stimulation will gradually train the brain to process sensory input more effectively. A major difference iLs has from the Tomatis approach and others, is to filter into higher frequencies of music more gradually and it also uses motor movement/throwing balls, balance activities, eye tracking and interactive language activities for improvements in the system. (O’Brien-Minson, 2014).

Supportive Evidence on Integrated Listening. A pilot study conducted to test the iLS therapeutic claims, found positive results including sensory and auditory improvements. However, it did not give support for the iLs programme as an evidence-based intervention for specifically improving auditory processing abilities since these were not explicitly tested (Schoen, Miller and Sullivan, 2015). Crucially, by testing behavioural or language only outcomes, these studies were not testing the specific processes the auditory training programme aimed (and claimed) to improve. This current study aims to administer the Scan 3: C test of auditory processing again at post-test, to examine evidence for a significant improvement in auditory processing. This evidence is crucial to support any claims for the programme causally affecting improvement in both sensory processing and also subsequent behaviour and cognition via improvements in auditory processing.

The pilot study of Schoen et al., (2015) discussed above, was a single- subject research design with only seven participants, the results could not be generalised to the larger population of children with sensory over responsivity and auditory processing challenges. Crucially, the design did not have a control group of comparable children to compare effects over time. Some evidence for physiological changes were reported using this auditory programme that delivered processed music, and gains were noted in performance in handwriting, reading and school work. As such, this exploratory study provided preliminary evidence that the iLs programme was effective in improving conditions for some of the children with sensory over-responsivity and auditory processing impairment but was not able to specifically identify improving auditory processing abilities as the causal factor in this improvement (Schoen, Miller and Sullivan, 2015).

The iLS system was specifically chosen as a study for this research as it was the most recent intervention therapy and appeared to combine all the current research to date. As a practising teacher, the researcher was eligible to undergo training from the iLS organisation in USA which enabled delivery of the intervention within the researcher's school. The current study seeks to more fully examine effects of the programme against a control of children over the same period. Furthermore, whilst the Scan 3:C test was just used initially in Schoen's study to identify the children with auditory issues for entry to the intervention group, this was also used in the study as a follow up test, post -intervention in this study, to gain possible causal information.

Summary, Research Aims and Hypotheses

Many of the studies to date have conflicting findings. This could be due to differences between different studies, such as; selection criteria of participants, assessment criteria, types of tests used and importantly, length of duration of intervention. Also, weaknesses within individual studies could contribute to varying results e.g. lack of treatment fidelity within the intervention, lack of consistency between testers (if more than one tester was involved) and inconsistency with home based parental input which is difficult to standardise.

Research within natural settings can be difficult and this study was carried out within a small school. As discussed, there can be problems maintaining fidelity of treatments and ensuring that treatments are administered reliably as they are intended (Asnaani, Gallagher, & Foa, 2018). There can also be constraints of time (e.g. time needed for preparation of the protocol sessions and for supervision) (Chard, Ricksecker, Healy, Karlin, & Resick, 2012). This researcher was fully trained in the use of the iLS system and received a certified qualification. A manualised protocol with a detailed instruction booklet was used in this study to ensure consistency of intervention across all the participants over time and adequate preparation time was allowed before each participant’s session. The researcher and the intervention practitioner in this study were the same person, thus ensuring consistency in implementation of the intervention across all subjects. This small school setting had limitations on the number of children who met the assessment criteria and also barriers to the availability of children for intervention times within the school day.

This study sought to identify a homogenous sample of children with sensory processing disorders within a school by testing their performance on a sensory processing scale (Sensory Processing Measure) and an auditory test (SCAN 3: C). Poor performance on the SPM test was used to indicate sensory processing difficulties (Parham, Ecker, Kuhaneck, Henry & Glennon, 2010) and low scores for the SCAN 3: C test to screen for auditory problems (Keith, 2000). The Integrated Listening System (iLS) programme, claims to improve both communication between the sensory systems (including the vestibular functions) and improve auditory processing and communication and integration with other sensory systems processing.

The study investigated whether the iLS system improved sensory processing and auditory functioning. The research literature discussed earlier has explored the common sensory issues underlying the diagnoses these participants have such as autism, dyslexia and general sensory motor processing problems. The participants in this study were treated as one group with underlying sensory processing issues for the purposes of this study.

Hypothesis (1) There would be a significant improvement in auditory abilities for the treatment group after iLS compared to the control group. This would be measured by an improvement in scores of the Scan 3:C auditory test (higher score).

Hypothesis (2) There would be a significant improvement in sensory processing skills (*7) (visual, hearing, touch, body and balance) for the treatment group after iLS compared to the control group. This would be measured by an improvement in the Sensory Processing Measure scores (lower score).

A manualised protocol was used to ensure consistency of intervention across all the participants. Also, a sensitive auditory battery of tests and a sensory processing measure able to target meaningful changes was used. A period of controlled waiting was used in study 1 and importantly, a separate control group used in study 2. Teachers were used to collect data on sensory processing at school and parents asked to complete the sensory processing measure at home. The programme was implemented solely within the school, within the school year. The same individual carried out assessments for each child, pre and post - test and children were not engaged in other therapies at the same time. Furthermore, the Scan 3:C test was used to identify the children with auditory issues for entry to the intervention group and also in the study as follow up test, post-intervention to measure any changes in auditory skills.

There were two approaches to collecting the data. Schoen's design (Schoen, 2015) was replicated in Study 1, whereby one group of children with special needs who had sensory processing difficulties completed all measures at baseline, time 1 (pre-intervention) and time 2 (post-intervention). However, in this study, the measures Scan 3:C and SPM were used as measures at these time points, rather than just as initial assessments tools as in Schoen's study. No change was predicted between baseline and pre- test (time1) (the period of controlled non-intervention), but a change was predicted between pre -intervention (time 1) to post-intervention (time 2) across all participants. Study 2 design incorporated an independent control group of children and an intervention (experimental) group with comparable learning (special) needs and sensory processing difficulties.

Due to time constraints, the first set of 4 participants did not have a period of 'waiting control'. After testing, they commenced the intervention immediately. The second set of participants had a 10 week period of 'no intervention' before they began their treatment. This allowed for the 2 x 2 design, comparing control group to treatment group, used in Study 2. After these two groups, there was a third group tested, again with a 10 week period of waiting control. Therefore, the second and third groups (each of 4 participants) had a baseline, waiting control and then an intervention period. This allowed for the 'waiting control' design used in Study 1 involving comparing baseline to after the waiting control period and the waiting control to after the intervention. The results for Study 1 and Study 2 could not be amalgamated as the initial group of 4 participants (Study 2) did not have an initial period of a 10 week 'waiting control'. For Study 2, see figure 3.

Study 1

Hypothesis (1) for Study 1 predicted an improvement in auditory abilities after iLS compared to the control condition (period of controlled non-intervention between baseline and pre-test before intervention). Therefore, it is predicted that there will be no difference between the auditory processing scores of the Scan 3: C auditory test at baseline and time 1(participants acting as their own control group with no intervention between times) but a difference between scores at time 1 and time 2, after the iLS intervention has occurred. Hypothesis (2) for Study 1 predicted an improvement in sensory processing skills after iLS compared to the control condition. Therefore, it is predicted that there will be no difference between the sensory processing scores of the SPM test at baseline and time 1 (participants acting as their own control group with no intervention between times) but a difference between sensory processing scores at time 1 and time 2, after the iLS intervention has taken place.

Method

Participants

Participants in the study included eight children of mean age 7 years and 5 months, 4 boys and 4 girls, attending a small Church of England School in Kent. All children were on the SEND register in the school and had a range of sensory processing issues as well as other issues associated with their main disorder (autism, dyslexia, ADHD, speech and language disorders) (see Appendix, Table 3). The parents were invited to participate based on evidence that studies in USA (Schoen, 2015) had indicated that there may be a benefit to the child. Inclusion criteria were: (1) sensory processing impairments reported to be interfering with performance at home or school based on parent or teacher report on the SPM scale and confirmed by the SEND (Special Educational Needs and Disabilities) coordinator within the school; (2) of primary school age and between the ages of 4-11; (3) parent or teacher report of auditory over-responsivity or auditory issues; (4) parent/child willingness to commit to the time needed for the programme within the school day and to parents' willingness to fill in the lengthy questionnaires.

The children did not partake in any other intervention during the period of the iLS protocol. Exclusion criteria included children diagnosed with seizure disorders, hearing issues, bipolar disorders, deafness and any other physical or neurological disorders. Also excluded, were children unable to tolerate wearing headphones for the 30 minutes required by the study design. In this study 1, the control and intervention groups were matched for age and differences were not statistically different ($p = .639994$).

Design

This study has built on the recommendations by Tashjian et al (2018) discussed earlier, that further studies should be completed during the school year. Teachers were used as part of the data collection process and the programme was implemented at school rather than at home, to minimise impact on family life. The auditory processing data (using the SCAN-3:C) was collected by the researcher at relevant time points and Sensory Processing Measure scale questionnaire filled in by teachers and parent at appropriate time points. A control group was used and the same individual carried out assessments for each child, pre and post- test. The environment was consistently school based (although the specific rooms did change). The intervention carried out within the school year and children were not engaged in other therapies at the same time and as such, this can be ruled out as a potential confounding factor.

A repeated measures design was used where children were tested at 3 time points on all measures. This design had a baseline phase, followed by a non- intervention phase and then a final intervention phase. Measurements were taken at baseline, then again following a phase of non-intervention of 10 weeks (pre-intervention measurement) and finally after a phase of intervention of 10 weeks (post-intervention). This design allows for performance on the main measures from baseline to pre-intervention to be compared to performance on the main measures at pre-intervention to post-intervention (i.e., following the phase on non-intervention). As such the participants acted as their own controls whereby change in performance across the 10 weeks on non-intervention can be compared to this group of children's change in performance across the 10 weeks of intervention. This design was suited to a school-based setting with one researcher and allowed flexibility in collecting the data, rather than having to collect all participant data concurrently. When this was repeated for multiple subjects, this design allowed for a systematic and cost-effective method for replication of results (Kennedy, 2005).

The repeated measures for this study were scores on a hearing test and sensory processing measure. Each participant's data was collected at baseline, then after a period of non-intervention of 10 weeks and again after a period of intervention of 10 weeks. The study examined the effects of an Integrated Listening System intervention on (1) auditory abilities and (2) sensory motor skills. It employed a questionnaire and standardised measures including the Scan 3: C auditory test and the Sensory Processing Measure (SPM). At baseline, hearing tests were conducted by the researcher and then again after the non- intervention phase. Also, at baseline and after the non- intervention phase, parents and teachers filled in the relevant SPM questionnaire (home or school version).

Each subject then completed 20 sessions of the Integrated Listening System Protocol. These 30 - minute sessions were listened to two/ three times a week using high quality, specialised headphones. The intervention lasted two school terms - ten weeks (excluding school term breaks). The playlists and music followed the sequence advised by the iLS organisation. After the intervention phase, the Scan 3: C tests and SPM questionnaires (home version and school version) were again administered to the children. In this approach, the independent variable is the time of testing (baseline, pre-test and post-test) and the dependent variables are the scores on the measures of (1) auditory abilities and (2) sensory motor skills.

Measures

Sensory Processing Measure (School and Home form). The SPM was used to measure the effectiveness of the iLS programme on sensory processing skills in school and the home. It includes social, visual, hearing, touch, body awareness, balance, and play contexts (Parham, Ecker, Kuhaneck, Henry & Glennon, 2010). The SPM involves a 4-point Likert scale (Never = 4, Occasionally = 3, Frequently = 2 and Always = 1) that assesses sensory processing difficulty, praxis and social participation in children by parents in the home, and teachers at school. For example, the Home Form Vision subscale involves 12 items (e.g. "seems bothered by light, especially bright light.") The Home Form Hearing subscale includes 8 items (e.g. "seems bothered by ordinary household sounds, such as vacuum cleaner, hair dryer or toilet flushing.") The School Form Touch subscale involves 8 items (e.g. "does not tolerate dirt on hands or clothing, even briefly.") and School Form's Balance and Motion involves a subscale of 9 items (e.g. "rocks in chair while seated at desk or table.") The current study focussed specifically on the sensory processing subscales within the SPM of vision, hearing, touch, body awareness, balance and motion.

The SPM is a multi-environment assessment that helps form a complete picture of the child and has established reliability and validity (Parham & Ecker, 2015). When the SPM was measured against the Short Sensory Profile, the Infant Toddler Sensory Profile and the Sensory Profile School Companion, the SPM demonstrated strong correlation to these other assessments (Parham & Ecker, 2015). Test-retest reliability refers to the stability of scores over time. In an examination of the SPM's test-retest reliability, children were tested in two pilot studies (Miller-Kuhaneck, Henry, Glennon, & Mu, 2007). The first study had an internal consistency result of .93 and .99. In the second pilot study, the internal consistency result was .70 to .99. Miller-Kuhaneck, Henry, Glennon, and Mu (2007) found the SPM correctly classified children with typical sensory processes 92.3% of the time. While children with sensory deficits were classified correctly 72% of the time. For the researchers, this adequately demonstrated the SPM's reliability and validity when discerning sensory processing deficits in children. The SPM can be used to provide critical information about whether sensory processing issues are, or are not, contributing to behavioural changes. The SPM is a valuable instrument in determining what type of interventions are appropriate for each child as well as in measuring the outcomes of therapy post-intervention.

The scaled forms were completed by parents, teachers and other professionals and were used to indicate a holistic view of children's sensory processing capabilities in the home and school. Higher scores indicated higher levels of sensory processing dysfunction. Raw scores and standardised age (and percentile ranks) were used to define the level of processing. The subscales of vision, hearing, touch, body awareness, balance and motion were collected and the raw total score for these 5 subscales calculated for an overall sensory processing score. Theses raw scores were age standardised according to the SPM manual. The SPM takes approximately 15-20 minutes to administer. Forms are typically used with ages 5-12 (Parham, Ecker, Kuhaneck, Henry & Glennon, 2010). Both raw and standardised scores were used as the raw scores were more sensitive in terms of absolute ability. The standardised scores were adjusting for age/level. As the sample was small, both scores were reported – to examine that either were not an artefact of scoring.

Scan- 3: C Auditory Test. The SCAN-3: C (Keith, 2009) is a standardized assessment of auditory processing skills for children between the ages 5.0 to 12.11. It is an individually administered battery of tests, designed to identify auditory processing disorders in children. The American Speech –Language -Hearing Association (ASHA, 1996; 2005) defines Auditory Processing Disorder (APD) as a deficiency in the perceptual processing of auditory information in the central nervous system as demonstrated by poor performance in one of more of the following skills; sound localisation and lateralisation, auditory pattern recognition, temporal aspects of audition, auditory performance with competing acoustic signals and/or auditory performance with degraded acoustic signals.

The Scan 3: C hearing test includes four subtests that represent functional auditory abilities in everyday listening situations: (1) The Filtered Words Subtest in which the subject is asked to repeat words that sound muffled. The test stimuli consist of monosyllabic words that have been low-pass filtered at 1000 Hz with a roll-off of 32 dB per octave. The test enables assessment of a child's ability to understand distorted speech, considered effective in identifying central auditory processing disorders. (2) The Auditory Figure-Ground Subtest which evaluates the subject's ability to understand words in the presence of background noise. Monosyllabic words were recorded in the presence of multi-talker speech babble noise at +8 dB signal-to-noise ratio. Poor performance on repeating the stimulus words may indicate a delay in development of the auditory system. (3) Competing Words Subtest in which the subject hears two words simultaneously-one monosyllabic word presented to each ear-and is instructed to repeat the words presented in each ear. The test enables assessment of ear advantage. Poor performance may indicate a delay in maturation, underlying neurological disorganisation, or damage to auditory pathways. Abnormalities shown by dichotic word test results are related to a wide range of specific disabilities, including CAPD, language disability, learning disability, and reading disorder. (4) The Competing Sentences Subtest includes pairs of sentences unrelated in topic which are presented to the right and left ears. The subject is instructed to direct attention to the stimuli presented in one ear while ignoring the other. Like the Competing Words subtest, the results are used to determine levels of auditory maturation, hemispheric dominance for language, and to identify disordered or damaged central auditory pathways (Keith, 2000). These tests have been shown to have high internal reliability and test-retest reliability (Keith, 2009) 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).

Reliability analyses for Study 1.

Reliability analyses were carried out on the measures within the Scan 3: C hearing test at baseline (see Appendix A). The Auditory Figure- Ground subscale consisted of 40 items ($\alpha = .76$ at baseline), the Filtered Words subscale consisted of 40 items ($\alpha = .77$ at baseline) and the Competing Words – Free Recall subscale also contained 40 items ($\alpha = .71$ at baseline). At above 0.7, these are considered to be reliable measures (Field, 2006).

Reliability analyses were carried out at baseline on the measures within the SPM test. For the SPM measure used at home (by the parent), the following reliability scores were obtained. The Visual subscale consisting of 11 items ($\alpha = .86$ at baseline), the Hearing subscale consisting of 8 items ($\alpha = .90$ at baseline), the Touch subscale containing 11 items ($\alpha = .75$ at baseline), the Body Awareness subscale consisting of 10 items ($\alpha = .57$ at baseline) and the Balance and Motion subscale consisting of 11 items ($\alpha = .80$ at baseline). All measures considered reliable as they achieve above 0.7, apart from Body Awareness subscale (Field, 2006).

For the school/ classroom based version of the SPM, used by teachers, the Visual subscale consisting of 7 items (α = .85 at baseline), the Hearing subscale consisting of 7 items (α = .72 at baseline), the Touch subscale containing 8 items (α = .88 at baseline), the Body Awareness subscale consisting of 7 items (α = .62 at baseline) and the Balance and Motion subscale consisting of 9 items (α = .59 at baseline, see Appendix A. Cronbach's Alpha Scores for Study 1). Scales of Visual, Hearing and Touch reached levels of reliability, but scales of Body Awareness and Balance and Motion did not, (Field, 2006). These low levels of reliability are commented on in the Limitations section.

Procedures

The study consisted of four stages:

(1) Administration of the baseline measures

(2) 10 weeks of no intervention, followed by pre-testing

(3) 10 weeks of intervention

(4) Post- testing.

As such, this Study 1 replicated the design of Schoen (2015), where the participants acted as their own controls (see Figure 2).

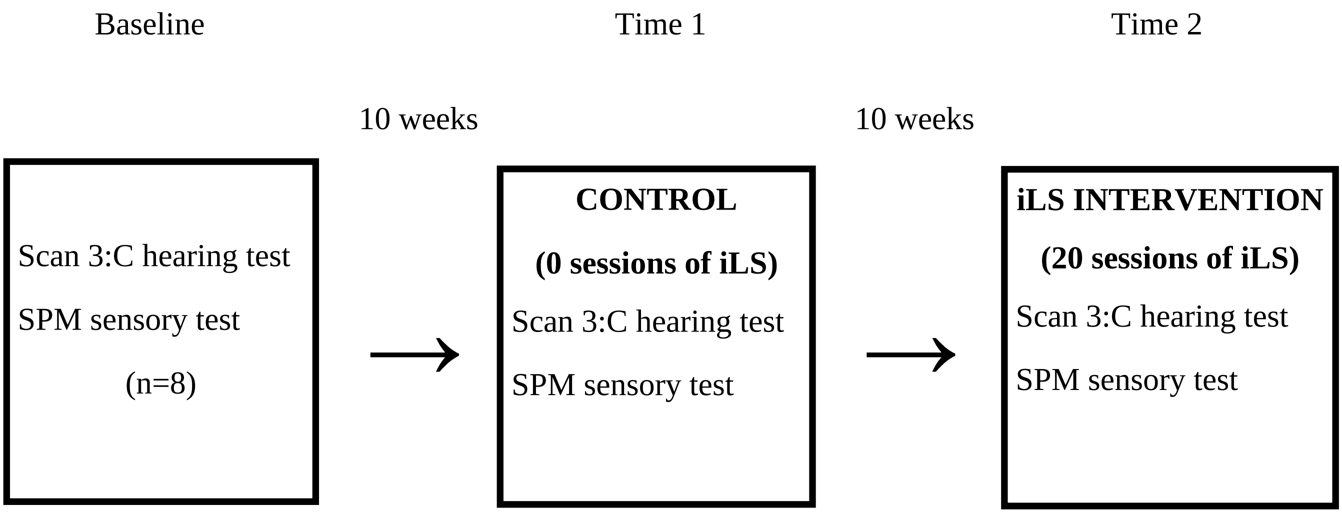

Figure 2. Intervention Schematic for iLS intervention - Study 1

Stage 1. Pretesting at baseline. Administration of the pre-test measures at the start of the study. Parents and teachers completed the Sensory Processing Measure for the child to fully characterise their sensory processing challenges. The Scan-3: C was also administered by the researcher to measure auditory processing difficulties.

Stage 2. Pretesting before intervention. Repeat administration of the pre-test measures after non- intervention phase of 10 weeks. Parents and teachers completed the Sensory Processing Measure for each child. The Scan-3: C was again administered by the practitioner for each child after this 10- week period of non- intervention.

Stage 3. Intervention. Intervention of twenty x 30 minute sessions of the iLS programme over 10 weeks. The programme was administered 2/3 times a week in school during the afternoons by the practitioner.

Stage 4. Post testing. After the 10 -week intervention**,** parents and teachers again completed the Sensory Processing Measure for children. Scan-3: C was administered by the researcher.

iLS Programme Intervention

The intervention consisted of 20 sessions using the iLs Focus Series sensory motor programme. (Integrated Listening Systems. Copyright 2018). The iLs programme is a protocol that uses specific classical music selections that are heard repeatedly. The programme is loaded onto an Apple iPod and delivered through a mini-amplifier with adjustable air- and bone-conduction volume to Sennheiser headphones custom fitted with bone-conduction capability. Specifically, the sensory motor programme emphasises frequencies at 750 Hz and lower. These lower frequencies emphasise input into the vestibular system and the body (iLS School Program Manual, Integrated Listening Systems, LLC 2014). 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 programme in a graded fashion, beginning gently and gradually increasing as the programme progresses.

The intervention approach used in this study involved using the iLS over a 10 week-period. Participants listened to the pre-programmed 2/3 days a week for 30 minutes. Each programme 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 child listens to the music via the headphones at the same time as performing the visual motor activities. The sets of visual motor activities included balance work, ball bouncing and catching, bean bag and eye-hand coordination games, such as bowling and target practice. 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 researcher (licensed to use this system) 2/3 times a week in the school.

Ethical considerations

The study was approved by The Ethics Chair of Social and Applied Sciences at Canterbury Christ Church University (Appendix G). Before the beginning of the intervention, the researcher collected signed, informed consent from the parents and verbal assent from the children to taking part after having the activities explained to them. Parents did not pay for the intervention nor were they required to purchase the iLs unit in order to participate in the study. They were given the right to discontinue the programme at any time. The researcher was aware of the impact an authority role as a teacher could have on the children, as a potential conflict of interest between the research role and as a teacher within the same school. This possibility had been identified when applying for Ethics Confirmation. All data has been securely stored on a password protected computer and within a locked cupboard on school premises. Participants were informed of their right to withdraw if they chose and that information would be kept confidential. The Integrated Listening System posed minimal risks to those who participated but proper precautions were taken to minimise those risks. A child may have had a negative reaction to the iLS programme after listening to the altered music – become overstressed or anxious, causing emotional distress. Risk of harm to the participant was minimised by monitoring the volume of the modified music and careful observation of the participant reactions by the researcher who is a qualified teacher and experienced in working with special needs. The researcher was licensed to use the system. The Risk Assessment points were followed for each session. All children taking part in the study were offered the training and had an opportunity to undertake it at some point in either Study 1 or Study 2.

Results

Study 1

Study 1 results showed no significant difference between scores at baseline and time 1 during the waiting control period but a significant difference in auditory processing scores after the intervention. This supported the hypotheses that there would be no difference between the auditory processing scores of the participants at baseline and time 1 (waiting control period) but a difference between time 1 and time 2, after the treatment. Auditory scores increased after the treatment indicating possible improved hearing abilities.

The sensory processing skills of the participants showed no significant differences after the waiting control period, as the hypotheses had predicted. However, no significant differences were found after the intervention either. This did not support the hypothesis that sensory processing skills could be malleable after such sensory processing interventions.

Descriptive statistics

The SPM questionnaire involved Likert scales considered to be interval data and therefore means were reported rather than medians.

The means and standard deviations for each of the main outcome measures at baseline, pre- intervention and post intervention are shown in Table 1, below.

Table 1. Means and standard deviations for Scan 3:C hearing test and Sensory Processing Measure – Study 1

			Time of test		
			Baseline	Time 1 (pre-test_	Time 2 (post-test)
Hearing Tests	Scan 3	Raw (not used)	-	-	-
	Scan 3	Standardised	7.75 (1.65)	7.63 (1.01)	9.92 (1.23)
Sensory Processing Tests	SPM Home	Raw	19.6 (4.8)	21.25 (5.06)	19.5 (5.25)
		Standardised	64.1 (7.07)	65.12 (7.47)	63.82 (7.49)
	SPM School	Raw	14.22 (3.73)	14.75 (3.07)	12.55 (2.21)
		Standardised	61.13 (5.30)	64.98 (5.79)	59.8 (5.93)

Notes. *Standard deviation in parenthesis.*

Scan 3: C – Hearing tests. Higher scores indicate better auditory abilities. SPM - Sensory Processing Measure. Higher scores indicate poorer sensory processing abilities. Raw Scan 3C not used as the participants' scores were used as a composite and needed to be age standardised to allow this.

Preliminary analysis

Examination of the main variables showed the small sample size had a non- normal distribution with skewness and kurtosis (see Appendix C). The data were also screened for outliers to assess for any impact of extreme values and 5 cases were found. Taken together with the small sample size it was concluded that nonparametric tests were to be utilised for the statistical analysis. This addresses the potential impact of outliers. One particular feature of nonparametric analysis is that it is minimally affected by extreme values because the size of the maximum value (99) does not affect the rank or the sign even if it is greater than 99. Wilcoxon test tests whether the difference between two observations has a mean signed rank of 0. Thus, it is much more robust against *outliers* and heavy tail distribution (Nahm, 2016). As a one sample, repeated measures design was used, then a Wilcoxon Signed Rank test was carried out (see Appendix E).

Hearing Tests. Scan 3: C analysis

Control Condition

A Wilcoxon Signed-Rank Test indicated that the time 1 hearing scores of the control group (M = 7.63) showed no statistical difference to their baseline scores (M = 7.75), Z = .254, p = .799 (see Table 1, Appendix E).

Intervention Condition

A Wilcoxon Signed-Rank Test indicated that the time 2 hearing scores of the intervention group (M = 9.92) showed a statistical difference to their time 1 scores after the training (M = 7.63), Z = -.254, p = .011 (see Table 1, Appendix E).

Hypothesis (1) for Study 1 had predicted an improvement in auditory abilities after iLS compared to the control group. It had predicted that there would be no difference between the auditory processing scores of the Scan 3: C auditory test at baseline and time 1(participants acting as their own control group with no intervention between times) but a difference between scores at time 1 and time 2, after the iLS intervention had occurred. Results therefore support this hypothesis. There was no significant difference in the scores of the control group before and after the control condition and a significant difference in the scores of the intervention condition pre and post-test. The intervention did result in increased hearing scores and may have improved hearing abilities.

Sensory Processing Measures analysis

Control Condition

Control Condition Home Raw

A Wilcoxon Signed-Rank Test indicated that the time 1 SPM scores of the control group (M = 21.25) showed no statistical difference to their baseline scores (M = 19.6),

Z = -1.33, p = .183 (see Table 1, Appendix E).

Control Condition Home Standardised

A Wilcoxon Signed-Rank-Test indicated that the time 1 SPM scores of the control group (M = 65.12) showed no statistical difference to their baseline scores (M = 64.1), Z = .56, p = .575 (see Table 1, Appendix E).

Control Condition School Raw

A Wilcoxon Signed-Rank Test indicated that the time 1 SPM scores of the control group (M = 14.75) showed no statistical difference to their baseline scores (M = 14.22), Z = -.34, p = .735 (see Table 1, Appendix E).

Control Condition School Standardised

A Wilcoxon Signed-Rank Test indicated that the time 1 SPM scores of the control group (M = 64.98) showed no statistical difference to their baseline scores (M = 61.13), Z = -1.82, p = .069 (see Table 1, Appendix E).

Intervention Condition

Intervention Condition Home Raw

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the intervention group (M = 19.5) showed no statistical difference to their time 1 scores (M = 21.25), Z = -1.36, p = .176 (see Table 1, Appendix E).

Intervention Condition Home Standardised

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the intervention group (M = 63.82) showed no statistical difference to their time 1 scores (M = 65.12), Z = -1.26, p = .208 (see Table 1, Appendix E).

Intervention Condition School Raw

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the intervention group (M = 12.55) showed no statistical difference to their time 1 scores (M = 14.75), Z = 1.82, p = .068 (see Table 1, Appendix E).

Intervention Condition School Standardised

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the intervention group (M = 19.5) showed no statistical difference to their time 1 scores (M = 21.25),

Z = -1.36, p = .176 (see Table 1, Appendix E).

Hypothesis (2) for Study 1 predicted an improvement in sensory processing skills after iLS compared to the control condition. Therefore, it was predicted that there would be no difference between the sensory processing scores of the SPM test at baseline and time 1 (participants acting as their own control group with no intervention between these times) but a difference between sensory processing scores at time 1 and time 2, after the iLS intervention has taken place.

Results supported the hypothesis that there would be no difference between the sensory processing scores of the SPM test at baseline and time 1 (control group). However, the results did not support the hypothesis that sensory processing skills would improve after intervention (experimental group). School and Home (raw and standardised) scores on their SPM questionnaires did not show a significant improvement pre to post-test.

It is worth noting however, that both the raw and standardised Sensory Processing Measure mean scores in School and Home did show a downward trend after the intervention (see Table 2). These lower scores indicated improvement but did not reach statistical significance for any category (see Appendix E).

Study 2

Study 1 used a comparable design to Schoen et al (2015) study using the iLS but included and actual measure of auditory ability and both teacher and home-based measures of sensory processing. As such, there was no independent control group to compare effects of the intervention (pre and post) to the effects of non-intervention (pre and post) for a similar group of children over concurrent period of time. A key criticism regarding sensory training programmes is that they lack evaluations using a proper independent control group (Leong, Carter, & Stephenson**,** 2015). As such, the following study used a more tightly controlled design with an independent control group of children and an intervention (experimental) group with comparable learning (special) needs and sensory processing difficulties. Study 2 consisted of 2 groups, a control (n =4) and an experimental (n=4), both tested at baseline (using Scan 3:C and SPM), then again at time 1, after the experimental group had received the intervention and the control group had not.

Hypothesis (1) for Study 2 predicted an improvement in auditory abilities after iLS compared to the control group. Therefore, it was predicted that there would be no difference between the auditory processing scores of the Scan 3: C auditory test at baseline and time 1 for the control group, but a difference between scores at time 1 and time 2, after the iLS intervention had occurred in the experimental group.

Hypothesis (2) for Study 2 predicted an improvement in sensory processing skills after iLS compared to the control group. Therefore, it was predicted that there would be no difference between the sensory processing scores of the SPM test at baseline and time 1 in the control group, but a difference between sensory processing scores at time 1 and time 2, after the iLS intervention had taken place in the experimental group.

Method

Participants

Participants in the study included eight children with a mean age of 6 years and 9 months, 5 boys and 3 girls, attending a small Church of England School in Kent. All children were on the SEND register in the school and had a range of sensory processing issues as well as other issues associated with their main disorder (autism, dyslexia, ADHD, speech and language disorders) (see Appendix, Table 4).

The parents were invited to participate based on evidence that studies in USA (Schoen, 2015) had indicated that there may be a benefit to the child. Inclusion criteria were as above in Study 1: (1) sensory processing impairments reported to be interfering with performance at home or school based on parent or teacher report on the SPM scale and confirmed by the SEND (Special Educational Needs and Disabilities) coordinator within the school; (2) of primary school age and between the ages of 4- 11; (3) parent or teacher report of auditory over-responsivity or auditory issues; (4) parent/child willingness to commit to the time needed for the programme within the school day and to parents' willingness to fill in the lengthy questionnaires. The children did not partake in any other intervention during the period of the iLS protocol. Exclusion criteria included children diagnosed with seizure disorders, hearing issues, bipolar disorders, deafness and any other physical or neurological disorders. Also excluded, were children unable to tolerate wearing headphones for the 30 minutes required by the study design.

Design

This study included an intervention group 1 and a control group 2. An initial pre-test was followed by an intervention phase for group 1 and no intervention for control group 2. Tests were given at pre-test and post intervention for groups 1 and 2. Though still suited to data collection with a school setting, this design was much more demanding in terms of time needed for the testing. As such, only a smaller sample size for the groups was practical.

The dependent measures for this study were scores on a hearing test and sensory processing measure for group 1 (intervention) and group 2 (control). As for Study 1, this study examined the effects of an Integrated Listening System intervention on (1) auditory abilities and (2) sensory motor skills. The Scan 3: C auditory test and the Sensory Processing Measure (SPM) questionnaires were again used. For group 1, pre-testing hearing tests were conducted by the researcher and then repeated after the intervention phase (post testing). Parents and teachers filled in the relevant SPM questionnaire (Home or School versions). Each subject again completed 20 sessions of the Integrated Listening System Protocol following the previous method of 30 - minute sessions listened to 2/ 3 times a week. The intervention was again carried out for approximately two school terms - ten weeks (excluding school term breaks).

Group 2 (control) were also tested on auditory and sensory measures at pre-test and again after 10 weeks at post-test but did not receive intervention during this time. These children within the control group did go on to do the intervention later and were included in the Study 1 analysis. The independent variable is the time of pre- test and post- test and the dependent variables are the scores made in the areas of (1) auditory abilities and (2) sensory motor skills. No matching was required for study 2, as there was no waiting control (just a comparison between pre and post- test).

Measures

Sensory Processing Measure (School and Home form): ***see previous description***

Scan- 3: C Auditory Test: ***see previous description***

Reliability analyses for Study 2.

Reliability analyses were carried out on the measures within the Scan 3: C hearing test at pre-test (time 1). The Auditory Figure- Ground (AFG) subscale consisted of 40 items (α =

.12 at time 1), the Filtered Words (FW) subscale consisted of 40 items (α = .66 at time 1) and the Competing Words – Free Recall (CW-FR) subscale also contained 40 items (α = .90 at time 1). Both the AFG and FW subscales did not reach internal reliability at they were below 0.7, however, the CWFR scale did achieve reliability (Field, 2006).

Reliability analyses were also carried out on the measures within the SPM test at time 1. The Home questionnaires - Visual subscale consisted of 11 items (α = .88 at time 1), the Hearing subscale consisted of 8 items (α = .80 at time 1), the Touch subscale contained 11 items (α = .42 at time 1), the Body Awareness subscale consisted of 10 items (α = .82 at time 1) and the Balance and Motion subscale consisted of 11 items (α = .75 at time 1). The School questionnaires - Visual subscale consisted of 7 items (α = .83 at time 1), the Hearing subscale consisted of 7 items (α = .72 at time 1), the Touch subscale contained 8 items (α = .80 at time 1), the Body Awareness subscale consisted of 7 items (α = .89 at time 1) and the Balance and Motion subscale consisted of 9 items (α = .95 at time 1). (See Appendix B. Cronbach's Alpha Scores for Study 2). All subscales reached the level of internal reliability at above 0.7, apart from the Touch subscale (Field, 2006). These low levels of reliability are again commented on in the Limitations section

(See Appendix B. Cronbach's Alpha Scores for Study 2).

Procedures

The study constituted 3 stages: (1) administration of the pre-test measures for groups 1 and 2, (2) intervention for 10 weeks for group 1 and no intervention for 10 weeks for control group 2, (3) post- testing for group 1 and control group 2.

Stage 1. Pretesting at time 1. Administration of the pre-test measures. Parents and teachers completed the Sensory Processing Measure for the child to fully characterise their sensory processing challenges (groups 1 and 2). The Scan-3: C was also administered by the researcher (groups 1 and 2) to assess for auditory processing difficulties**.**

Stage 2. Intervention. Intervention of twenty x 30 minute sessions of the iLS programme over 10 weeks for group 1. The programme was administered 2/ 3 times a week in school during the afternoons by the practitioner. No intervention for group 2.

Stage 3. Post testing. Parents and teachers completed the Sensory Processing Measure for children in groups 1 and 2. Scan-3: C was administered by the researcher (groups 1 and 2).

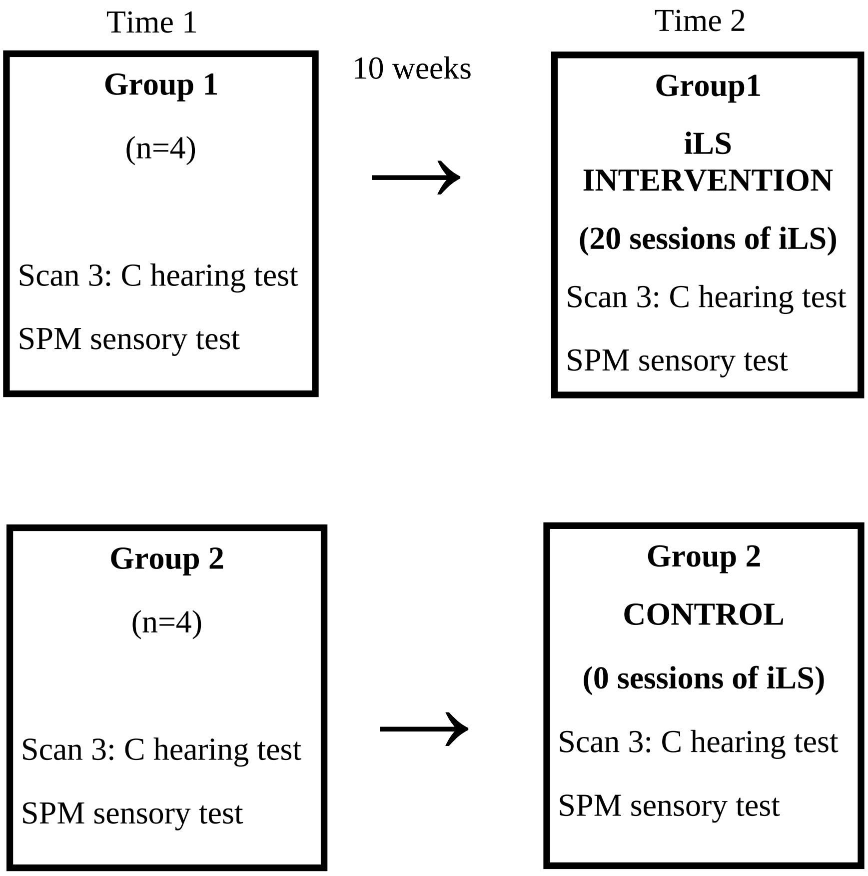

Figure 3. Intervention Schematic for iLS intervention - Study 2

The intervention again consisted of 20 sessions using the iLs Focus Series sensory motor programme (see previous description of materials and procedures. Intervention sessions were completed by the researcher 2 / 3 times a week in the school.

Ethical Considerations

(see previous description)

Results

Study 2

Study 2 results showed that both the control group and the intervention group showed no statistical difference in their hearing abilities or sensory processing abilities after retesting at time 2. This supported the hypotheses that there would be no difference in the control group between time 1 and time 2, but did not support the hypotheses that the intervention would improve hearing and sensory processing abilities in the intervention group

Descriptive statistics

Preliminary analysis

Preliminary examination carried out again showed the small sample size had a non-normal distribution with skewness, kurtosis and 1 outlier (see Appendix D), concluding nonparametric tests were to be utilised for the statistical analysis (see Appendix F). Each group was analysed separately to compare the difference in scores on dependent variables from pre (time1) to post (time 2) using Wilcoxon. The means and standard deviations for each of the main measures at pre- intervention and post intervention are shown in Table 2, below.

Table 2. Means and standard deviations for Scan 3:C and Sensory Processing Measure with control and experimental groups-Study 2

	Control		Experimental		Total	
	Pre -test (time1)	Post test (time 2)	Pre- test (time1)	Post test (time 2)	Pre -test (time1)	Post test (time 2)
HEARING TEST						
Scan 3 Raw (not used)						
Scan 3 Standardised	7.5 (0.82)	7.5(0.83)	10.08 (0.74)	11.75(0.88)	8.79 (1.57)	9.63(2.41)
SENSORY TEST						
SPM Raw (Home)	20.15 (5.74)	22.6 (4.42)	22.15 (2.61)	21.1 (3.20)	21.15 (4.27)	21.85 (3.66)
SPM Raw (School)	14.05 (4.11)	15.2 (2.8)	17.35(3.9)	17.0 (6.99)	15.70 (4.11)	16.1 (5.02)
SPM Stand (Home)	64.80 (8.4)	68.7 (5.16)	68.5 (3.04)	67.95 (2.83)	66.65 (6.17)	68.33 (3.87)
SPM Stand (School)	63.55 (6.73)	65.5 (4.25)	67.45 (6.98)	58.85(12.09)	65.5 (6.68)	62.18 (9.11)

Notes. *Standard deviation in parenthesis.*

Scan 3: C – Hearing tests. Higher scores indicate better auditory abilities

SPM - Sensory Processing Measure. Higher scores indicate poorer sensory processing abilities

Hearing Tests. Scan 3: C analysis

Control Condition

A Wilcoxon Signed-Rank Test indicated that the time 2 hearing scores of the control group (M = 7.5) showed no statistical difference to their time 1 scores (M = 7.5), Z = 0.0, p =1.00 (see Table 2 and Appendix F).

Intervention Condition

A Wilcoxon Signed-Rank Test indicated that the time 2 hearing scores of the control group (M = 11.75) showed no statistical difference to their time 1 scores (M = 10.08), Z = -1.84, p = .066 (see Table 2 and Appendix F).

Sensory Processing Measures analysis

Control Condition

Home Measure

In the Sensory Processing Measure, a Wilcoxon Signed-Rank Test, indicated that the time 2 SPM scores of the Home Raw control group (M = 22.6) showed no statistical difference to their time 1 scores (M = 20.15), Z = -1.1, p = 0.273. This was repeated in the age adjusted Home Standardised score, with no statistical difference between time 1 (M = 64.80) and time 2 (M= 68.7), Z = -1.46, p = 0.144. (See Table 2 and Appendix F).

School Measure

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the School Raw control group (M = 15.2) showed no statistical difference to their time 1 scores

(M = 14.05), Z = -1.07, p = 0.285. This was repeated in the age adjusted School Standardised score, with no statistical difference between time 1 (M = 63.55) and School Standardised control score, time 2 (M= 65.5), Z = -1.1, p = 0.273 (see Table 2 and Appendix F).

Intervention Condition

Home Measure

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the Home Raw experimental group (M = 21.1) showed no statistical difference to their time 1 scores (M = 22.15), Z = -7.30, p = 0.47. This was repeated in the age adjusted Home Standardised score, with no statistical difference between time 1 (M = 68.5) and Home Standardised control score, time 2 (M= 67.95), Z = 0.0, p = 1.00 (see Table 2 and Appendix F).

School Measure

A Wilcoxon Signed-Rank Test indicated that the time 2 SPM scores of the School Raw experimental group (M = 17.0) showed no statistical difference from their time 1 scores (M = 17.35), Z = -3.7, p = 0.715. This was repeated in the age adjusted School Standardised score, with no statistical difference between time 1 (M = 67.45) and School Standardised control score, time 2 (M= 58.85), Z = -1.83, p = 0.068 (see Table 2 and Appendix F).

Neither the control or intervention groups showed significant differences from pre-test to post- test in either the raw or standardised scores on the SPM measure. This indicates that although there was a trend towards lower improved scores for the intervention group, these results were not statistically significant in terms of improving the sensory processing of the participants. As such there is no evidence for the intervention having any more effect than that shown for the non-intervention control group (who also showed no significant change over the same time period). It is interesting to note the downward trend after intervention with the sensory processing scores occurred for both the groups in Study 1 and Study 2. Further studies need to be carried out to determine whether this improving downward trend would have continued with more exposure to the intervention i.e. with the recommended 40 -60 x 1 hour sessions rather than the 20 half hour sessions which were delivered in this study.

A correction was not made for multiple testing. A large number of tests were checking baseline differences. Corrections were not made when there were multiple tests for a hypothesis, however, non-parametric tests were used. While parametric analysis focuses on the difference in the means of the groups to be compared, nonparametric analysis focuses on the rank, thereby putting more emphasis differences of the median values than the mean. Nonparametric analysis converts the original data in the order of size and only uses the rank or signs. Although this can result in a loss of information of the original data, nonparametric analysis has more statistical power than parametric analysis when the data are not normally distributed (as with my data). Ten Wilcoxon Signed- Rank tests were carried out in study 1 and 10 Wilcoxon Signed-Rank tests in study 2. Out of these tests, the hearing Scan 3:C hearing intervention condition in study 1 showed a significant difference after the training

(p =.011), which would not be significant after a Bonferroni correction.

Discussion

The current exploratory study examined whether there would be improvement in auditory processing abilities and sensory processing skills following the iLS programme, a specialised auditory and sensory training intervention. The iLS programme considers that it is therapeutic listening combined with a sensory diet which is effective in improving behaviours related to sensory processing in children with SPD and visual motor impairments (O'Brien-Minson, 2014). The iLS system claims to improve more than just auditory processing but also global brain functioning and language and cognitive processes (ILSA, 2015). Limited research has been carried out to evaluate this programme. Schoen et al., (2015) had conducted a pilot study to test the iLS therapeutic claims and found positive results including sensory and auditory improvements. However, it had not given support for the iLs programme as an evidence-based intervention for specifically improving auditory processing abilities since these had not been explicitly tested. Also, a period of non-intervention control had been used rather than an independent control group. This study aimed to address this by including a specific measure of auditory ability (SCAN 3:C) and Sensory Processing Measure (SPM) and using both a non-intervention control period (Study 1) and an independent control group (Study 2) to examine the effects of the intervention using the iLS training programme.

Hypothesis (1) predicted an improvement in auditory abilities after iLS compared to the control conditions. An increase in the Scan 3:C scores was therefore predicted. Hypothesis (2) predicted an improvement in sensory processing skills after iLS compared to the control conditions. This would result in a decrease in the SPM scores.

The results in Study 1 provide some support for the efficacy of iLS intervention in terms of auditory improvements. There were improved scores in the Scan 3: C hearing test for the intervention group after they had experienced the iLS intervention after time 2 as opposed to their period of no intervention at time 1. Hypothesis (1) which predicted improved auditory abilities after iLS compared to the control condition was supported. However, results in Study 2, though showing some improvement, were not significant, a situation that was similar to the control group. However, the sample size for the intervention group in study 2 was much smaller than study 1 which may have limited its ability to detect any effect.

Schoen's original pilot study in 2015 provided preliminary research that the iLs programme was effective in improving conditions for some of the children with sensory over-responsivity and auditory processing impairment but was not able to specifically identify improving auditory processing abilities as the causal factor in this improvement. Study 1 has some evidence that auditory abilities have been specifically improved by exposure to the iLS intervention and has been able to add to the support of the iLS system as being a possible vehicle for improving auditory processing skills. The iLS system is built on the research of Tomatis that the ear plays a significant role in sensory processing and overall organisation of the nervous system (Frick & Hacker, 2001; Labbé, Schmidt, Babin, & Pharr, 2007). As such, findings from study 1 indicates partial support for initial improvements occurring in ear.

Although there was a trend towards lower scores in the Sensory Processing Measure for participants in both Study 1 and Study 2, indicating an improvement in sensory processing skills, this trend was not statistically significant. As such, Hypothesis (2) was not supported. This may in part reflect the fact that the intervention had taken place for only 20 x 30 minute sessions, as opposed to the recommended 40 -60 x 1 hour sessions, and the significance of this shorter time span will be discussed later.

However, these mixed results may be explained by the concept that when experiencing treatment, the child may become more disorganized before demonstrating organized behaviour (Gilfoyle, Grady & Moore, 1990). Varied results may be an indication that the child experienced disorganization before reorganization, or regression before progression (Gilfoyle, Grady, & Moore, 1990). If the results of the study are supported by this notion, then future research may benefit from an extended length of study.

This current study had several advantages compared to previous studies. As well as the replication of the repeated measures design involving a period of non-intervention control, used previously by Schoen (2015), this study also included an independent control group design, which no other studies included (Preto, Malloy & Luong, 2017; Schoen 2015). Also, and importantly, the same researcher carried out interventions for all children ensuring consistency in delivery of the programme. Many other studies have incorporated several different therapists and parents as well to implement the training (Preto, Malloy, & Luong, 2017). This cannot ensure that protocols are carried in a standardised way for all participants. Moreover, as well as ensuring consistency in terms of having the same researcher deliver the programme, it also had the advantage of iLS system's instructional 'Playbook'. This presents the exercises in an ordered sequence, developing in difficulty. It is straightforward to implement and ensured consistency between groups in terms of delivery to the different children.

The sample size was comparable to some studies, Schoen (2015), Gee et al (2014), but smaller than others, Bazyk, Cimmo, Hayes, Goodman and Farrell (2010). This reflected the practical demands of the delivery of this intense intervention programme, within the constraints of the school day and limited staff to deliver the programme. Other studies have used larger numbers of children, but this has involved a variety of therapists which has led to inconsistent collection of data and omissions (Preto, Malloy & Luong, 2017) – there was no missing data for the current studies. This study also carried out the recommendation to deliver intervention in school time and consider gathering feedback from participants' teachers (Preto, Malloy & Luong, 2017). There were a small, manageable number of assessments. Following Preto, Malloy and Luong (2017) who had 6 assessments and recommended fewer to ensure more simplified data collection. This study had 2 assessments - the SPM and Scan-3:C.

Limitations of the study and recommendations

Although the current study did provide some support for the efficacy of the iLS training to improve auditory weakness, there are several limitations which need to be discussed. First and foremost was the length of time of the study. Typically, the iLS programme is provided on an average of 3 to 6 months or 40-60 x 1 hour sessions. This study was completed in only ten weeks and, due to time constraints, only delivered 20 x 30 minute sessions. This was only a quarter of the recommended number and therefore a weaker result could be expected. Also, again due to practical time constraints, the intervention was only carried out for 2/3 sessions per week instead of five. With school holidays usually falling within the 10- week period, there were several weeks where the intervention could only be delivered twice instead of three times. This lower intensity may also have affected the result. Importantly, in addition, a longer recommended time period may also be required not just only in terms of number of sessions, but to also allow the intervention time to embed within the participant's system (Doidge, 2016).

In the key studies included earlier in the thesis, the time scale for these sensory interventions had also been much longer. Hall & Case-Smith (2007) carried out two therapeutic listening treatment sessions per day for 8 weeks**.** Bazyk, Cimino, Hayes, Goodman, and Farrell (2010) used their intervention for twenty minutes twice a day during periods of typical classroom routine. The duration of the intervention varied from six weeks to five months. Preto, Malloy and Luong (2017) used an intervention consisting of a 15-minute session administered twice daily, seven days a week for a total of eight weeks. Tashjian, Hair and Taasan (2018) used twelve weeks of a sensory intervention with a 30-minutes twice daily music session. These key studies have all used much longer periods of intervention before testing the efficacy of any sensory processing treatment.

Second, a further limitation was sample size. Some of the Cronbach's Alpha scores for the Scan 3:C hearing test and SPM scales, were low in reliability. They were conducted on small sample sizes and therefore, any results should be interpreted with caution. Future studies may need to use other scales with greater reliability. Analysis on the effect sizes suggest that there is potentially an effect, but again, sample size is too small to pick this up (see Table 6). Further studies should aim for an increased sample size. A third limitation is that the same researcher conducted the intervention as performed the auditory measure (SCAN 3: C) so assessor was not blinded to pre- test and post- test administration. Fourth, the SPM is a subjective measure and reflects an interpretation of the child's performance. It is possible for parents and teachers to unknowingly alter their expectations for performance over the intervention period though it is important to note this measure is well validated (Miller-Kuhaneck, Henry, Glennon, & Mu, 2007; Parham & Ecker, 2015). Fifth, results may not be generalisable to all populations of children with sensory processing difficulties due to the small sample size.

A sixth limitation was that, although the intervention was always performed in school, there were unfortunately still a variety of rooms due to rooming constraints. This may have affected the delivery of the intervention and a consistent dedicated room would have been preferable. Finally, it is possible that there may be practice effects from using the same measures at pre and post testing. Pemberton (2016) in her study of auditory training for children with deficits in auditory processing, suggests that future researchers evaluating these auditory training programmes could use different measures for the same narrow ability. These auditory abilities could be classified according to The Cattell-Horn-Carroll (CHC) taxonomy of intelligence (McGrew, 2009) pre and post intervention, and the order of these tests changed between individuals, to control for order effects.

The study was limited in its scope to 6-9 year olds, and so results cannot be assumed to be applicable to older children. A longer period of implementation is recommended for the intervention as this study only delivered 20 of the recommended 40 sessions. There may be a period of disorganisation before improvements are see, and researchers need to allow time to pass (Gilfoyle, Grady & Moore, 1990). Although consistency of practitioner is needed for all children throughout intervention, a further recommendation would be to utilise a second person to be the assessor to ensure independence of measurement. In addition, another improvement would be to use a randomised – control design. This is difficult within a school set up as there may be restrictions on which children who can be withdrawn. Some children may be eligible for other interventions outside the iLS and there needs to be a balance between ensuring that no other interventions taking place (confounding the possible effects of the iLS) with the needs of the child. Denying the child exposure to alternative interventions is not ethical. Also, withdrawing children from their lessons and ensuring they still have access to the curriculum, requires careful planning within a mainstream school. The intervention should be performed within a consistent school setting, preferably with a dedicated room, and carried out in school time so as not to impact on family life. Despite the limitations, the current study does show some supporting evidence for the effectiveness of auditory training programmes.

Conclusion

The study shows partial support for the iLS system as an intervention to address hearing issues within the range of sensory processing problems. It would be important that further studies could explore whether a longer exposure to the iLS programme (40-60 sessions of 1 hour) would result in statistically significant benefits to the sensory processing skills of the participants and also to the auditory abilities of all the participants. This study has shown some support in terms of auditory improvements, but would have benefited greatly from a quadrupling of time in line with the recommendations of the iLS programme itself. Additionally, a larger sample base across several schools would be of benefit in future studies. The iLS programme is feasible to run within a school setting and allows an intervention to be administered alongside the school- based curriculum. The programme could be carried out by school staff and does not need the attention and cost of an occupational therapist nor a teacher. The study hopes to have contributed to current literature on iLS and auditory – based interventions with an evidence -based practice approach. The iLs system is an enjoyable therapy and great fun to participate and administer.

References

Accordino, R., Comer, & Heller, W.B. (2007). Searching for music's potential: A critical examination of research on music therapy with individuals with autism. *Research in Autism Spectrum Disorders*, *1*(1), 101-115. doi:10.1016/j.rasd.2006.08.002

Adams, J. N., Feldman, H. M., Huffman, L. C., & Loe, I. M. (2015). Sensory processing in preterm pre-schoolers and its association with executive function. *Early Human Development*, *91*, 227–233.

Advanced Brain Technologies (2009). The Listening Program Training Manual. Ogden, Utah: ABT.

Advanced Brain Technologies (2013). The Listening Program. (Available at: http://www.thelisteningprogram. com [4 January 2013].

Al-Ayadhi, L. Y., Al-Drees, A. M., & Al-Arfaj, A. M. (2013). Effectiveness of Auditory Integration Therapy in Autism spectrum Disorders—prospective study. *Autism Insights,* 5, 13-20

American Academy of Pediatrics Committee on Children with Disabilities (1998). Auditory integration training and facilitated communication for autism. *Pediatrics*, *102*, 431-433.

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Menta (1 June 2013). dsmpsychiatryonline.org. *Disorders, Fifth Edition. Arlington, VA, American Psychiatric Association, Web*.

American Psychiatric Association. (2013a). Diagnostic and statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing. *American Psychiatric Association.* (2013b).What is autism spectrum disorder? Retrieved from https://www.psychiatry.org/ patieies/autism/what-is-autism-spectrum-disorder

Anderson, S., & Kraus, N. (2010). Sensory-cognitive interaction in the neural encoding of speech in noise: a review**.** *Journal American Academy Audiology, 21 (9), 575–85***.** doi*:*10.3766/jaaa.21.9.3**.** PMC 3075209 **.** PMID 21241645**.**

Angeli, S. (2003). Value of vestibular testing in young children with sensorineural hearing loss. *Arch Otolaryngol Head Neck Surgery, 129*:478-82.

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional and behavioural and educational outcomes in children with autism spectrum disorder. *The American Journal of Occupational Therapy, 62* (5), 564-573.

Asherson, P. (2004). Attention-deficit hyperactivity disorder in the post-genomic era. *European Child Adolescent Psychiatry 13,* (1), I50–I70

Asnaani, A., Gallagher, T., & Foa, E. B. (2018). Evidence-based protocols: Merits, drawbacks, and potential solutions. *Clinical Psychology: Science and Practice, 25,* e12266.

Ayres, A.J. (1972). *Sensory integration and learning disorders*. Los Angeles: Western Psychological Services

Ayres, A.J. (1979). *Sensory integration and the child.* Los Angeles, CA: Western Psychological Services

Ayres, J. (2013). Sensory Integration and the Child. Los Angeles: Western Psychological Services.

Azevedo, M.G., & Samelli, A. G. (2009). Comparative study of balance on deaf and hearing children. Rev CEFAC; 11 (Suppl 1):85-91

Baranek, G.T. (2007). Efficacy of Sensory and Motor Interventions for Children with Autism *Journal of Autism and Developmental Disorders, 32*(5), 397-422

Barrera, M. E., Rykov, M. H., & Doyle, S. L. (2002). The effects of interactive music therapy on hospitalized children with cancer: A pilot study. *Psycho-Oncology, 11*(5), 379-388. doi:10.1002/pon.589

Bazyk, S., Cimino, J., Hayes, K., Goodman, G., & Farrell, P. (2010). The use of therapeutic listening with pre-schoolers with developmental disabilities: A look at the outcomes. *Journal of Occupational Therapy, Schools, & Early Intervention*, *3*(2), 124–138. doi:10.1080/19411243.2010.491013

Ben-Sasson, A., Carter, A. S. & Briggs-Gowan, M. J. (2010). The Development of Sensory Over-responsivity From Infancy to Elementary School. *Journal of Abnormal Child Psychology, 38* (8), 1193- 1202. doi.org/10.1007/s10802-010-9435-9

Ben-Sasson, A., Soto, T.W., Heberle, A., Carter, A.S., & Briggs-Gowan, M.J. (2014). Early and concurrent features of **A**DHD and Sensory Over-Responsivity Clusters. *Journal of Attention Disorders, (21)*10, 835-845.

Berthoz, A. (2000). The Brain's Sense of Movement. Harvard University Press, Cambridge, Mass, Google Scholar

Bettison, S. (1996). The long-term effects of auditory integration training on children with autism. *Journal of Autism and Developmental Disorders*, *26*, 361–374.

Blanche, E. I., & Parham, L. D. (2001). Praxis and organization of behavior in time and space. In S. Smith Roley, E. I. Blanche, & R. Schaaf (Eds.), Understanding the nature of sensory integration with diverse populations (183–200). San Antonio, TX: Therapy Skill Builders.

Boatman, D. F. (2006). Cortical auditory systems: Speech and other complex sounds. *Epilepsy and Behavior, 8,* 494-503.

Bundy, A. C., Lane, S. J., & Murray, E. A. (2002). Sensory integration: Theory and practice (2nd ed.). Philadelphia: F. A. Davis.

British Society of Audiology (2011. Position Statement on Auditory Processing Disorder. [Online]. Available from: ftp://ftp.phon.ucl.ac.uk/pub/andyf/BSA_APD_ Position_Consultation.pdf. [Accessed 23rd November 2016].

Case-Smith, J., Weaver, L., & Fristad, M. (2014). A systematic review of sensory processing interventions for children with autism spectrum disorders. *Autism, 19* (2), 133-148. doi:10.1177/1362361313517762

Chang, M., Parham, L., Blanche, E., Schell, A., Chou, C., Dawson, M., & Clark, F. (2012). Autonomic and behavioral responses of children with autism to auditory stimuli. *The American Journal of Occupational Therapy*. *66*(5), 567-76. doi:10.5014/ajot.2012.004242.

Chard, K., Ricksecker, E., Healy, E., Karlin, B., & Resick, P. (2012). Dissemination and experience with cognitive processing therapy. *Journal of Rehabilitation Research and Development, 49*(5), 667– 668. https://doi.org/10.1682/JRRD.2011.10.0198

Cohen, A. (2013). Vision rehabilitation for visual- vestibular dysfunction: The role of the neuro-optometrist. *Neuro Rehabilitation, 32,* (3), 483-492

Corbett, B., Shickman, K., & Ferrer, E. (2008). Brief Report: The Effects of Tomatis Sound Therapy on Language in Children with Autism. *Journal of autism and developmental disorders, 38*5, 62-6. doi:10.1007/s10803-007-0413-1.

Cullen, K.E. (2012). The Vestibular system: multimodal integration and encoding of self - motion for motor control. *Trends in Neuroscience, 3* (3), 185-196

Dabbous, A. O. (2012). Characteristics of auditory brainstem response latencies in children with autism spectrum disorders. *Journal Audiological Medicine, 10* (3). doi:10.3109/1651386X.2012.708986

Daud, M., Noor, K & H., Rahman, R., & A., Normastura & Sidek, D.S. &Mohamad, Amran, D., & M., (2009). The effect of mild hearing loss on academic performance in primary school children. *International journal of pediatric otorhinolaryngology,* (*74)* 67-70. 10.1016/j.ijporl.2009.10.013.

Davis, D. (2005). A Review of Various Abilities Improved after the Basic Tomatis Method Program for Autistic, Williams Syndrome and AD/HD clients, presented at the 2005 Educational Audiology Association Summer Conference.

Dawes, P., & Bishop, D. (2009). Auditory processing disorder in relation to developmental disorders of language, communication and attention: A review and critique. *International Journal of Language and Communication Disorders, 44,* 440-465.

de Wit, E., Visser-Bochane, M. I., Steenbergen, B., van Dijk, P., van der Schans, C. P. & Luinge, M. R. (2016). Characteristics of auditory processing disorders: a systematic review. *Journal of Speech, Language, and Hearing Research, 59*(2), 384-413.

DeVore, B., Nagao, K., Pereira, O., Nemith, J., Sklar, R., Deeves, E., Kish, E., Welsh, K., & Morlet, T. (2016). Speech errors among children with auditory processing disorder. *Proceedings of Meetings on Acoustics, 29 (1) 6.* doi**:**10.1121/2.0000440**.**

De Vries, D., Beck, T., Stacey, B., Winslow, K., & Meines, K. (2015). Music as a therapeutic intervention with autism: A systematic review of the literature. *Therapeutic Recreation Journal, 49*(3), 220-237.

Doidge, N. (2016). Neuroplasticity and Healing: A Clinical Conversation with Norman Doidge, MD, and Robert Rountree, MD. *Alternative and Complementary Therapies, 22* (5),

181-188.

Edelson, S. M., Arin, D., Bauman, M., Lukas, S. E., Rudy, J. H., Sholar, M., & Rimland, B. (1999). Auditory integration training: A double- blind study of behavioral and electrophysiological effects in people with autism. *Focus on Autism and Other Developmental Disabilities, 14*(2), 73-81.

Eysenck, M. W., & Keane, M. T. (2013). Cognitive Psychology: A student's handbook. Psychology press.

Field, A.P. (2005). Discovering Statistics Using SPSS (2nd Edition) London: Sage

Formigoni, F.G. (1998). Avaliação vestibular na criança. In: Ganança MM, editor. *Vertigem tem cura* São Paulo: Lemos; 117-26.

Foss- Feig, J. H., Schauder, K.B., Key, A.P., Wallace, M.T., & Stone, W.L. (2017). Audition-specific temporal processing deficits associated with language function in children with autism spectrum disorder. *Autism Research*, *10* (11), 1845-1856.

Frick, S. M., & Hacker, C. (2001). Listening with the whole body. Vital Links; Madison, WI:

Frick, S., & Young, S. (2009). Listening with the whole body: clinical concepts and treatment guidelines for therapeutic listening. Vital Links; Madison, W1.

Gee, B., Thompson, K., & St John, H. (2014). Efficacy of a Sound-based Intervention with a Child with an Autism Spectrum Disorder and Auditory Sensory Over-responsivity. *Occupational Therapy International*, *21*, 12-20. doi:10.12968/ijtr.2015.22.1.36

Ghanizadeh, A. (2011). Sensory Processing Problems in Children with ADHD, a Systematic Review. *Psychiatry Investigation*, *8*(2) 89-94. doi:10.4306/pi.2011.8.2.89

Gilfoyle, E., Grady, A., Moore, J. (1990). Children adapt (2nd ed.). Thorofare, NJ: Slack

Gillberg, C., Johansson, M., Steffenburg, S., Berlin, O. (1997). Auditory Integration Training in Children with Autism. Brief Report of an Open Pilot Study. *The National Autistic Society*, *1*(1) 97–100. doi:10.1177/1362361397011009

Gilmor, T.M. (1999). The Efficacy of the Tomatis method for Children with Learning and Communication Disorders. *International Journal of Listening*, *13*, 12-23.

Gomes, H., Duff, M., Ramos, M., Molholm, S., Foxe, J. J., & Halperin, J. (2012). Auditory selective attention and processing in children with attention-deficit/hyperactivity disorder. *Clinical Neurophysiology, 123*(2), 293-302. doi:10.1016/j.clinph.2011.07.030

Gunning, T. G. (2002). Assessing and correcting reading and writing difficulties. Boston: Allyn and Bacon.

Hall, L., & Case-Smith, J. (2007). The effect of sound-based intervention on children with sensory processing disorders and visual-motor delays. *The American Journal of Occupational Therapy, 61*, 209-215

Hamalainen, J.A., Rupp, A., Soltesz, F., Szucs, D., and Goswami, U. (2012). Reduced phase locking to slow amplitude modulation in adults with dyslexia: an MEG study. *Neuroimage, 59*, 2952-2961.doi:10.1016/j.neuroimage.2011.09.075

Hochreutener, S. L. (2016). Play in music therapy with children. *Nordic Journal of Music Therapy, 25*, 104-104. doi:10.1080/08098131.2016.1180114

Integrated Listening Systems © Copyright 2018. 2851 S. Parker Road, Suite 800, Aurora, CO 80014 (303) 741-4544

Janarthanan, S.D. (2017). Visual processing disorder in children. *Ophthalmology Open Journal*. *2*(2): 45-47. doi: 10.17140/OOJ2-113

Jung, H., Woo, J., Kang, J., Choi.,Y., Kim, K. (2014). Visual Perception of ADHD Children with Sensory Processing Disorder. *Psychiatry Investigation, 11*(2).

Kaga, K. (1999). Vestibular compensation in infants and children with congenital and acquired vestibular loss in both ears. *International Journal of Pediatric Otorhinolaryngology*, *49*, 215-224.

Kaga, K, Shinjo Y, Jin Y, Takegoshi H. (2008). Vestibular failure in children with congenital deafness. *International Journal of Audiology*, *47*, 590-9.

Kandel, E., Schwartz, J., & Jessell, T. (1991). Principles of neural science (3rd ed.), Appleton and Lange, Norwalk, Connecticut. Google Scholar

Kargas, N., López, B., Reddy, V., & Morris, P. (2015). The relationship between auditory processing and restricted, repetitive behaviors in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *45*(3), 658-668. doi:10.1007/s10803-014-2219-2

Keith, R., W. (2000). Development and Standardization of SCAN-C Test for Auditory Processing Disorders in Children. *Journal of the American Academy of Audiology*, *11*, 438–445.

Keith, R. W. (2009). Scan-3: C Test for auditory processing disorders in children. *San Antonio, TX: PsychCorp*

Kershner, J. R., Cummings, R. L., Clarke, K. A., Hadfield, A. J., & Kershner, B. A. (1990). Two- year evaluation of the tomatis listening training programmeme with learning disabled children. *Learning Disability Quarterly*, *13*(1), 43-53. doi:10.2307/1510391

Klein, A. J., Armstrong, B.L., Greer, M.K., & Brown, III, F.R. (1990). Hyperacusis and otitis media in individuals with Williams Syndrome. *Journal of Speech and Hearing Disorders*, *55*, 339-344.

Kovačević, J., & Jachova, Z., (2016). Balance and Orientation of Hearing Impaired Children. *Research in Physical Education, Sport and Health, 5* (2), 27-31.

Kranowitz, C.S., (1996-7). The Vestibular System and Auditory Language Processing, The Out-of-Sync Child: Understanding and Coping with Sensory Integration Dysfunction. *New Developments, 2* (3).

Labbé, E., Schmidt, N., Babin, J., & Pharr, M. (2007). Coping with stress: The effectiveness of different types of music. *Applied Psychophysiology and Biofeedback, 32*(3-4), 163.

Lallier, M., Donnadieu,S., & Valdois, S. (2013). Investigating the role of visual and auditory search in reading and developmental dyslexia. *Frontiers of Human Neuroscience, 7,* Article 597. doi:10.3389/fnhum.2013.00597

Leong, H.M., Carter, M. & Stephenson, J. (2015). Meta-analysis of Research on Sensory Integration Therapy for Individuals with Developmental and Learning Disabilities. *J.R. Journal of Developmental and Physical Disabilities*, 27: 183. doi:1007/s10882-014-9408-y

Lovett, M. W. (1987). A developmental approach to reading disability: Accuracy and speed criteria of normal and deficient reading skill. *Child Development, 58,* 234-260.

Lovett, B.J. (2011). Auditory processing disorder: School psychologist beware? *Psychology in the schools*, 48(8), 855-867.

Lyon, G., Shaywitz, S.E., & Shaywitz, B.A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53,* 1–14.

May-Benson, T. A., & Koomar, J. A. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy, 64*, 403-414.

McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence, 37*(1), 1-10.

Miller, L. J. (2003). Empirical evidence related to therapies for sensory processing impairments. *Communiqué, 31*(5), 34–37.

Miller, L. J., Schoen, S., Coll, J., Brett-Green, B., & Reale, M. (2005). Final report: Quantitative psychophysiologic examination of sensory processing in children with autism spectrum disorders. *Cure Autism Now*. Los Angeles, CA

Miller, L. J. (2006). Miller function and participation scales manual. San Antonio, TX: Pearson.

Miller, L. (2006, 2014). Sensational Kids: Hope and Help for Children with Sensory Processing Disorder. New York: Penguin Group.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy, 61*(2), 135–140. doi:10.5014/ajot.61.2.135

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *American Journal of Occupational Therapy, 61*(2), 228-238.

Miller-Kuhaneck, Henry, Glennon, & Mu, (2007). The Sensory Processing Measure Preschool (SPM-P)-Part One: Description of the Tool and Its Use in the Preschool Environment, *Journal of Occupational Therapy, Schools, & Early Intervention, 4*:42–52, 2011 Copyright © Taylor & Francis Group, LLC ISSN: 1941-1243 print / 1941-1251 doi 10.1080/19411243.2011.573245

Moore, D. (2011). The diagnosis and management of auditory processing disorder. *Language, Speech, and Hearing Services in Schools, 42*(3), 303-308.

Mudford, O. (2000). Auditory Integration Training: Recent UK Study. *Autism, 4* (3*),337-338.* doi:10.1177/1362361300004003009

Neysmith-Roy, J. (2001). The Tomatis method with severely autistic boys: Individual case studies of behavioral changes. *South African Journal of Psychology; South African Journal of Psychology, 31*(1), 19.

Northern, J.L., Downs, M.P. (1989). Hearing in Children. 3rd ed. São Paulo: Manole

O'Brien-Minson, K. (2014). What is iLs. Integrated Listening Systems? Retrieved September 29, 2015, from http://integratedlistening.com/parents/what-is-ils/

Ortiz, R., Estévez, A., Muñetón, M., & Domínguez, C. (2014). Visual and auditory perception in preschool children at risk for dyslexia. *Research in Developmental Disabilities, 35*(11), 2673-2680. doi:10.1016/j.ridd.2014.07.007

Parham, D., & Ecker, C. (2007). Sensory Processing Measure manual. Los Angeles: Western Psychological Services.

Parham, L. D. (2002). Sensory integration and occupation. In A. C. Bundy, S. J. Lane, & E. A. Murray (Eds.), Sensory integration theory and practice, 2nd ed., 413–434. Philadelphia: F. A. Davis

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (2007). Somatosensory function in boys with ADHD and tactile defensiveness. *Physiology & Behavior, 90(*4), 553-558.

Pemberton, R.A. (2016). Auditory Training for Children with Deficits in Auditory Processing: An Exploratory Study. Retrieved from https://neurocareclinics.com.au/wp-content/uploads/2018/06/ATP-Uni-of-Melb-Thesis-Summary-2016.pdf

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of Sensory Integration interventions in children with autism spectrum disorders: A pilot study. *The American Journal of Occupational Therapy*, *65*(1), 76-85.

Pfeiffer, B.A., Clark, G. F., & Arbesman, M. (2018). Effectiveness of Cognitive and Occupation-Based Interventions for Children with Challenges in Sensory Processing and Integration: A Systematic Review. *American Journal of Occupational Therapy, 72* (1), 1-9.

Polanczyk, G., de Lima, MS., Horta, B.L., Biederman, J., Rohde, L.A. (2007). The worldwide prevalence of ADHD: a systematic review and meta- regression analysis. *American Journal of Psychiatry, 164*, 942–948.

Preto, S., Malloy, A., & Luong, B. (2017). Efficacy of Therapeutic Listening®-Quickshifts in children with sensory processing difficulties. Master's Theses and Capstone Projects, 246. http://scholar.dominican.edu/masters-theses/246.

Randell, E. (2019). Sensory integration therapy versus usual care for sensory processing difficulties in autism spectrum disorder in children: study protocol for a pragmatic randomised controlled trial. *Trials, 20* (1)) ISSN: 1745-6215

Rimland, B., & Edelson, R. (1994). The effects of auditory integration training on autism. *American Journal of Speech and Language Pathology, 5*, 16–24.

Rimland, B., & Edelson, R. (1995). Brief report: A pilot study of auditory integration training on autism. *Journal of Autism and Developmental Disorders*, *31*, 61–71.

Rosen, S., Cohen, M. & Vanniasegram, I. (2010). Auditory and cognitive abilities of children suspected with auditory processing disorder (APD). *International Journal of Paediatric Otorhinolaryngology, 74(*6), 594-600.

Ruben, S. (2004). Awakening Ashley. How Mozart knocks Autism on its ear, iUniverse, Inc

Sarant**,** J., Harris**,** D., & Bennet, L.(2015). Academic Outcomes for School-Aged Children with Severe‐Profound Hearing Loss and Early Unilateral and Bilateral Cochlear Implants. *Journal of Speech, Language, and Hearing Research*, *58*, 1017-1032.

Schoen, S. A., Miller, L. J., Brett-Green, B. A. & Nielsen, D. M. (2009). Physiological and behavioral differences in sensory processing: a comparison of children with Autism Spectrum Disorder and Sensory Modulation Disorder. *Frontiers in Integrative Neuroscience 3*(29). doi:10.3389/neuro.07029.2009

Schoen, S. A., Miller, L. J., & Sullivan, J. (2015). A pilot study of integrated listening systems for children with sensory processing problems. *Journal of Occupational Therapy, Schools, & Early Intervention, 8* (3), 256-276. doi:10.1080/19411243.2015.1055418

Serrallach, B., Groß, C., Bernhofs, V., Engelmann, D., Benner, J., Gündert, N., Seither-Preisler, A. (2016). Neural biomarkers for dyslexia, ADHD, and ADD in the auditory cortex of children. *Frontiers in Neuroscience, 10.* doi:10.3389/fnins.2016.00324

Shaywitz, S.E., Shaywitz, B.A. (2008). Paying attention to reading: The neurobiology of reading and dyslexia. *Development and Psychopathology, 20,* 1329–1349.

Shum, S., Pang, Y. (2009). Children with attention deficit hyperactivity disorder have impaired balance function: involvement of somatosensory, visual and vestibular systems, *Journal of Pediatrics, 155*, 245-249.

Shumway-Cook, A., Woollacott, M. H. (2001). Motor control: theory and practical applications. Baltimore, MD: Williams & Wilkins

Sinha, Y., Silove, N., Wheeler, D., & Williams, K. (2006). Auditory integration training and other sound therapies for autism spectrum disorders: A systematic review. *Archives of Disease in Childhood, 91*(12), 1018. doi:10.1136/adc.2006.094649

Sloan, C. (1991). Treating auditory processing difficulties in children (Clinical updates in speech-language pathology series). San Diego, California: Singular Publishing Group.

Smith Roley, S., Blanche, E. I., & Schaaf, R. C. (Eds.). (2001). Understanding the nature of sensory integration with diverse populations. San Antonio, TX: Therapy Skill Builders

Smith Roley, S., & Jacobs, S. (2008). Sensory integration. In E. B. Crepeau, E. S. Cohn, & B. A. B. Schell (Eds.), Willard and Spackman's occupational therapy (11th ed., 792–817). Philadelphia: Lippincott Williams & Wilkins.

Snowling, M. J. (2013). Early identification and interventions for dyslexia: A contemporary view. *Journal of Research in Special Educational Needs, 13*(1), 7-14.

Stefanics, G., Fosker, T., Huss, M., Mead, N., Szucs, D., & Goswami, U. (2011). Sensory deficits in developmental dyslexia: A longitudinal ERP study. *NeuroImage, 57*(3), 723-732. doi:10.1016/j.neuroimage.2011.04.005

Sternberg, R.J., & Sternberg, K. (2014). Cognitive Psychology. Connecticut: Centage Learning

Stiegler, L. N., & Davis, R. (2010). Understanding sound sensitivity in individuals with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *25*(2), 67-75.

Strait, D., Parbery-Clark, A., Hittner, E., & Kraus, N. (2012). Musical training during early childhood enhances the neural encoding of speech in noise. *Brain and language*, *123*. doi: 10.1016/j.bandl.2012.09.001.

Stutt, H.A. (1983). The Tomatis method. A review of current research.

Swanson, J.M., Wigal, T., & Lakes, K. (2009). DSM-V and the future diagnosis of attention-deficit/hyperactivity disorder. *Current Psychiatry Reports, 11*, 399–406

Talay-Ongan, A., & Wood, K. (2000). Unusual sensory sensitivities in autism: A possible crossroads. *International Journal of Disability, Development and Education, 47*(2), 201-212. doi:10.1080/713671112

Tashjian, H., Hair, D., & Taasan, P. (2018). Measuring the Outcomes of Therapeutic Listening in Children with Learning and Developmental Disabilities. *Master's Theses and Capstone Projects*. 292. https://scholar.dominican.edu/masters-theses/292

Thompson, B. M., & Andrews, S. R. (2000). An historical commentary on physiological effects of music: Tomatis, Mozart, and neuropsychology. *Integrative Physiological and Behavioural Science, 35*, 174–188.

Van Mourik, R., Sergeant, J. A., Heslenfeld, D., Konig, C., & Oosterlaan, J. (2011). Auditory conflict processing in ADHD. *Journal of Child Psychology and Psychiatry, 52*(3), 265-274. doi:10.1111/j.1469-7610.2010.02339.x

Vanzetta I., & Grinvald, A. (2008). Coupling between neuronal activity and microcirculation: implications for functional brain imaging. *Hfsp Journal, 2* (2), *79–98.* doi:10.2976/1.2889618. PMC 2645573. PMID 19404475.

Watling, R., Koenig, K., Davies, P., & Schaaf, R. (2011). Occupational therapy practice guidelines for children and adolescents with difficulty processing and integration sensory information. Bethseda, MD: AOTA Press.

Watling, R., & Hauer, S. (2015). Effectiveness of Ayres Sensory Integration® and sensory-based interventions for people with autism spectrum disorder: A systematic review. *American Journal of Occupational Therapy, 69*(5), 6905180030p1-6905180030p12.

Wiener- Vacher, S.J. (2008). Vestibular disorders in children. *International Journal of Audiology, 47* (8). doi.org/10.1080/14992020802334358

Wong, C., Odom, S. L., Hume, K. A., Cox, A. W., Fettig, A., Kucharczyk, S., Schultz, T. R. (2015). Evidence- based practices for children, youth, and young adults with autism spectrum disorder: A comprehensive review. *Journal of Autism and Developmental Disorders, 45*(7), 1951-1966. doi:10.1007/s10803-014-2351-z

Yalcinkaya, F., Muluk, N. & Sahin, S. (2009). Effects of listening ability on speaking, writing, and reading skills of children who were suspected of auditory processing difficulty. *International Journal of Paediatric Otorhinolaryngology, 73*(8), 1137-1142.

Appendices

Appendix A.

Reliability analyses for Study 1.

Cronbach's Alpha for Study 1

	Baseline Home		Baseline School		Time 1 Home		Time 1 School		Time 2 Home		Time 2 School	
	Raw	Standard	Raw	Standard	Raw	Standard	Raw	Standard	Raw	Standard	Raw	Standard
Scan 3 AFG	-	-	-	.764	-	-	-	.631	-	-	-	.627
Scan 3 FW	-	-	-	.774	-	-	-	.719	-	-	-	.477
Scan 3 CW-FR	-	-	-	.713	-	-	-	.615	-	-	-	.302
SPM VISUAL	.864	-	.847	-	.887	-	.888	-	.842	-	.706	-
SPM HEARING	.898	-	.720	-	.903	-	.434	-	.947	-	.646	-
SPM TOUCH	.745	-	.874	-	.878	-	.775	-	.856	-	.608	-
SPM BODY	.569	-	.615	-	.070	-	.846	-	.656	-	.814	-
SPM BALANCE	.798	-	.593	-	.818	-	.786	-	.755	-	.890	-

Notes. *Scan 3:C – hearing tests. SPM - Sensory Processing Measure.*

Scan 3: C does not have a Home Test and only age corrected standardised scores were used for Scan 3: C as different aged children were compared. Cronbach's Alpha was only performed on the raw scores of the SPM.

AFG – Auditory Figure Ground FW- Filtered Words CW – Competing Words- Free Recall

Appendix B.

Reliability analyses for Study 2.

Cronbach's Alpha for Study 2

		Baseline Home		Baseline School		Time 1 Home		Time 1 School	
		Raw	Standard	Raw	Standard	Raw	Standard	Raw	Standard
Scan 3:C Hearing test	AFG	-	-	-	.121	-	-	-	.335
	FW	-	-	-	.659	-	-	-	.672
	CW-FR	-	-	-	.898	-	-	-	.883
Sensory Processing Measure	Visual	.800	-	.830	-	.795	-	.916	-
	Hearing	.803	-	.716	-	.810	-	.665	-
	Touch	.417	-	.793	-	.787	-	.688	-
	Body	.824	-	.892	-	.775	-	.855	-
	Balance	.747	-	.947	-	.725	-	.944	-

Note. *Scan 3: C – hearing tests. SPM - Sensory Processing Measure*.

Scan 3: C does not have a Home Test and only age corrected standardised scores were used for Scan 3:C as different aged children were compared as a composite score. Cronbach's Alpha only performed on the raw scores of the SPM.

AFG – Auditory Figure Ground FW- Filtered Words CW – Competing Words- Free Recall

Appendix C.
Skewness and Kurtosis for Study 1.

	Skewness			Kurtosis		
	Statistic	Standard error	Z score	Statistic	Standard error	Z score
Mean Scan 3 Stand Baseline	0.819	0.752	1.089	1.951	1.481	1.317
Mean Scan 3 Standard Time 1	-0.572	0.752	-0.761	-0.427	1.481	-0.289
Mean Scan 3 Standard Time 2	0.241	0.752	0.320	0.258	1.481	0.174
Mean SPM Baseline Raw Home	-0.113	0.752	-0.150	-0.448	1.481	-0.302
Mean SPM Time 1 Raw Home	-0.855	0.752	-1.137	-1.248	1.481	-0.842
Mean SPM Time 2 Raw Home	-0.07	0.752	-0.093	-2.050	1.481	-1.384
Mean SPM Baseline Standard Home	-0.324	0.752	-0.430	-0.743	1.481	-0.502
Mean SPM Time 1 Standard Home	-1.082	0.752	-1.439	-0.256	1.481	-0.173
Mean SPM Time 2 Standard Home	-0.495	0.752	-0.658	-1.754	1.481	-1.184
Mean SPM Baseline Raw School	2.282	0.752	3.034	5.824	1.481	3.932
Mean SPM Time 1 Raw School	0.010	0.752	0.013	-0.615	1.481	-0.415
Mean SPM Time 2 Raw School	-1.059	0.752	-1.408	0.578	1.481	0.390
Mean SPM Baseline Standard School	2.258	0.752	3.003	5.898	1.481	3.982
Mean SPM Time 1 Standard School	-1.031	0.752	-1.371	1.377	1.481	0.930
Mean SPM Time 2 Standard School	-1.676	0.752	-2.229	3.102	1.481	2.094

Note. *Scan 3: C – hearing tests* *SPM - Sensory Processing Measure*

As some of the scores were less than -1.96 and greater than 1.96, then skewness and kurtosis were statistically significant at $p < 0.05$.

Therefore, non-parametric tests were used.

Appendix D.

Skewness and Kurtosis for Study 2.

		Skewness			Kurtosis		
		Statistic	Standard error	Z score	Statistic	Standard error	Z score
Mean Scan 3 Stand Baseline	Control	-0.286	2.619	0.19	0.864	1.014	0.852
	Experimental	-1.700	2.619	-0.650	0.482	1.014	0.475
Mean Scan 3 Standard Time 1	Control	2.227	2.619	0.850	-1.129	1.014	-1.113
	Experimental	2.235	2.619	0.853	1.443	1.014	1.423
Mean SPM Baseline Raw Home	Control	1.207	2.619	-0.864	0.51	1.014	0.502
	Experimental	-1.397	2.619	-0.533	-0.702	1.014	-0.692
Mean SPM Time 1 Raw Home	Control	3.800	2.619	1.450	-1.944	1.014	-1.917
	Experimental	1.404	2.619	0.536	0.368	1.014	0.363
Mean SPM Baseline Standard Home	Control	0.848	2.619	0.323	-0.468	1.014	-0.462
	Experimental	-0.181	2.619	-0.069	-1.048	1.014	-1.034
Mean SPM Time 1 Standard Home	Control	3.808	2.619	1.453	-1.937	1.014	-1.910
	Experimental	1.957	2.619	0.747	0.922	1.014	0.909
Mean SPM Baseline Raw School	Control	3.875	2.619	1.480	1.962	1.014	1.934
	Experimental	1.037	2.619	0.40	0.892	1.014	0.879
Mean SPM Time 1 Raw School	Control	1.202	2.619	0.46	0.413	1.014	0.407
	Experimental	-1.649	2.619	-0.630	-0.258	1.014	-0.254
Mean SPM Baseline Standard School	Control	3.813	2.619	1.460	1.944	1.014	1.917
	Experimental	0.123	2.619	0.047	-0.628	1.014	-0.619
Mean SPM Time 1 Standard School	Control	1.511	2.619	0.577	0.141	1.014	0.139
	Experimental	-3.792	2.619	-1.448	0.374	1.014	0.369

Note. *Scan 3: C – hearing tests. SPM - Sensory Processing Measure*

Appendix E.

Wilcoxon matched-pairs. Study 1.

Scan 3

1) Standardised (std) Scan 3 Baseline - Pre. Retain null. No sig diff (0.799), Z = - .25
2) Std Scan 3 Pre - Post. Reject null. Sig difference (0.011), Z = - 2.54

SPM Home

3) Raw SPM Baseline – Pre. Retain null. No sig diff. (0.183), Z = -1.33
4) Raw SPM Pre- Post. Retain null. No sig diff. (0.176), Z = -1.36
5) Std SPM Baseline -Pre. Retain null. No sig diff. (0.575), Z = -.56
6) Std SPM Pre- Post. Retain null. No sig diff. (0.208), Z = -1.26

SPM School

1) Raw SPM Baseline – Pre. Retain null. No sig diff. (0.735), Z = -.34
2) Raw SPM Pre- Post – Retain null. No sig diff. (0.068), Z = 1.82
3) Std SPM Baseline – Pre. Retain null. No sig diff. (0.069), Z = -1.82
4) Std SPM Pre- Post – Retain null. No sig (0.068), Z = -1.82

Appendix F.

Wilcoxon matched-pairs. Study 2.

Control

Scan 3

1) Std Scan 3 pre to post- test. Retain null. No sig diff (p=1.00), Z= 0.0

SPM Home

2) Raw SPM Home, pre- post-test. Retain null. No sig diff. (0.273), Z = -1.1
3) Std SPM Home, pre- post- test. Retain null. No sig diff. (0.144), Z = -1.46

SPM School

4) Raw SPM School, pre- post-test. Retain null. No sig diff. (0.285), Z = -1.07
5) Std SPM School, pre- post- test. Retain null. No sig diff. (0.273), Z = =1.1

Experimental

Scan 3

1) Std Scan 3 pre to post- test. Retain null. No sig diff (0.066), Z = -1.84

SPM Home

2) Raw SPM Home, pre- post-test. Retain null. No sig diff. (0.465), Z = -7.30
3) Std SPM Home, pre- post- test. Retain null. No sig diff. (1.00), Z = 0.0

SPM School

4) Raw SPM School, pre- post-test. Retain null. No sig diff. (0.715), Z = -3.7
5) Std SPM School, pre- post- test. Retain null. No sig diff. (0.068), Z = - 1.83

Appendix G.

Confirmation of Ethics Compliance.

Canterbury Christ Church University

11th September 2017 Ref: 16/SAS/363F

Debra Cluff

c/o School of Psychology, Politics and Sociology

Faculty of Social & Applied Science

Dear Debra

Confirmation of ethics compliance for your study *"Improving children's auditory and sensory skills: An evaluation of the effectiveness of the intervention 'Integrated Listening Systems' (iLS) for children with sensory processing difficulties."*

Your application complies fully with the requirements for full ethical review as set out in this University's Research Ethics and Governance Procedures.

In confirming compliance for your study, I must remind you that it is your responsibility to follow, as appropriate, the policies and procedures set out in the *Research Governance Framework*(http://www.canterbury.ac.uk/research-and-consultancy/governance-and-ethics/governance-and-ethics.aspx) and any relevant academic or professional guidelines. This includes providing, if appropriate, information sheets and consent forms, and ensuring confidentiality in the storage and use of data. Any significant change in the question, design or conduct of the study over its course should be notified to the **Ethics Chair of Social & Applied Sciences**, and may require a new application for ethics approval. It is a condition of compliance that you **must** inform me once your research has been completed.

Wishing you every success with your research.

Yours sincerely

Carol Clewlow

(On behalf on Dr Dennis Nigbur)

Carol Clewlow

RKE Co-Ordinator

Tel: +44 (0)1227 922893 (direct line)

Email: red.resgov@canterbury.ac.uk

CC: Dr. Nicola Abbott and Dr. Lance Slad

Appendix H. *Consent form for Parent/Guardian*

Canterbury Christ Church University

TITLE OF RESEARCH PROJECT

Improving children's aúditory and sensory skills: An evaluation of the effectiveness of the intervention 'Integrated Listening Systems' (iLS) for children with sensory processing difficulties.

PARTICIPANT INFORMATION SHEET - PARENT/ GUARDIAN

A research study is being conducted at Canterbury Christ Church University (CCCU) by Debra Cluff and Dr Nicola Abbott

Background

The study will test how effective a new intervention program from USA, is on improving the auditory processing and sensory skills of children with sensory processing problems. The program is called 'Integrated Listening Systems' (iLS) and has been shown in studies to develop the listening, sensory and concentration skills of these children and as a consequence, improve their school behaviour and reading and writing levels.

What will participants be required to do?

Participants will attend sessions three times a week for half an hour. They will wear headphones through which classical music is played and will simultaneously perform physical tasks (such as throwing and catching balls/ playing games). These sessions will take place for approximately 12 weeks.

To participate in this research you must:

- Attend Deal Parochial Church of England School, Deal, Kent
- Already be on the school's SEND list
- Have issues with auditory or sensory skills.

Procedures

Children participating will attend sessions three times a week for half an hour. They will wear headphones through which (treated) classical music is played and will simultaneously perform physical tasks (such as throwing /catching balls and playing games). The children will leave their class and take part in the program on Tuesday, Wednesday and Thursday afternoons. Times will be scheduled to cause minimum disruption to their lessons.

Parents and teachers will be asked to fill in questionnaires about the sensory skills of the child involved, before and after the intervention. Also parents and teachers will be invited to take part in interviews where they share any experiences about the effect of the intervention on the child. Further information will be sent to you about this.

Confidentiality

All data and personal information will be stored securely within Deal Parochial C of E Primary School and CCCU premises in accordance with the Data Protection Act 1998 and the University's own data protection requirements. Data will be anonymised from the beginning of the project. A unique code will be used in place of all names on intervention sheets, data spreadsheets and questionnaires. Names and codes will be stored separately from each other. Data can only be accessed by Debra Cluff (researcher) , Dr Nicola Abbott, Dr Lance Slade (supervisors), Mrs Justine Brown (headteacher) and Mrs Hogben (SEND coordinator).

Dissemination of results

The results will form the basis of a dissertation which Debra Cluff is submitting for an MSc in Psychology at Canterbury University, a journal article and conference poster. Also, summary data and statistics in anonymous form may be shared with other interested schools. Children's personal details will not be included in this. A summary of the findings will be made available to the parents and the school in line with general policy of data sharing with parents by the school.

Deciding whether to participate

If you have any questions or concerns about the nature, procedures or requirements for participation do not hesitate to contact me. Should you decide to participate, you will be free to withdraw at any time without having to give a reason.

Any questions?

Please contact **Debra Cluff** on:
01304374464
cluffd@deal-parochial.kent.sch.uk.

Dr Nicola Abbott
School of Psychology, Politics and Sociology
Canterbury Christchurch University
North Holmes Road
Canterbury
CT1 1QU
Tel: 01227 863088
nicola.abbott@canterbury.ac.uk

PARENTAL/ GUARDIAN CONSENT

I give consent for my child to take part in this intervention project at Deal Parochial Church of England Primary School

Signed .... Child's name.......................................

Print name................................. Date...

Appendix I. *Consent form for Teacher*

Canterbury Christ Church University

TITLE OF RESEARCH PROJECT

Improving children's auditory and sensory skills: An evaluation of the effectiveness of the intervention 'Integrated Listening Systems' (iLS) for children with sensory processing difficulties.

PARTICIPANT INFORMATION SHEET - TEACHER

A research study is being conducted at Canterbury Christ Church University (CCCU) by Debra Cluff and Dr Nicola Abbott

Background

Children with special educational needs often have difficulties with auditory and sensory skills. This project examines the possibility that these skills can be improved. Such children may include children with autism, dyslexia and ADHD. Research has indicated these three conditions may have a common link in difficulties in auditory and/ or sensory processing. A new intervention has been pioneered in America called 'iLS' (Integrated Listening Systems) which seeks to improve auditory and sensory integration and processing.

The study will evaluate the effectiveness of the iLS system in an educational setting. This evaluation will include standardized measures directly related to measuring improved sensory processing using the Sensory Processing Measure. A further 10 questions will be added into the SPM specifically asking about attentional control and to examine if changes in sensory processing result in changes of attention.

The Scan- 3:C test will also be used as a battery of tests which screen and diagnose auditory processing difficulties in children. Pre -and post tests will be used to measure any improvements in auditory and sensory skills. The data will also be compared to teacher observation of a child's ability in the classroom and parent experiences at home.

The intervention will be for 30 sessions (3 times a week). One or two children can be included in each session.

What will participants be required to do?

Participants will attend sessions three times a week for half an hour. They will wear headphones through which classical music is played and will simultaneously perform physical tasks (such as throwing and catching balls). These sessions will take place for approximately 12 weeks.

To participate in this research you must:

- Attend Deal Parochial Church of England School, Deal, Kent
- Already be on the school's SEND list
- Achieve pre- measure scores on the Scan-3:C test and Sensory Processing Scale indicating auditory / sensory issues

Procedures

TEACHER'S CONSENT

I consent to participation in this project at Deal Parochial Church of England Primary School

Signed ……………………………………………………………

Print name…………………………………………………………
Class teacher

Date…………………………………………………………

Appendix J. Consent form for Head teacher.

Canterbury Christ Church University

TITLE OF RESEARCH PROJECT

Improving children's auditory and sensory skills: An evaluation of the effectiveness of the intervention 'Integrated Listening Systems' (iLS) for children with sensory processing difficulties.

PARTICIPANT INFORMATION SHEET - HEADTEACHER

A research study is being conducted at Canterbury Christ Church University (CCCU) by Debra Cluff,

Dr Nicola Abbott and Dr Lance Slade.

Background

Children with special educational needs often have difficulties with auditory and sensory skills. This project examines the possibility that these skills can be improved. Such children may include children with autism, dyslexia and ADHD. Research has indicated these three conditions may have a common link in difficulties in auditory and/ or sensory processing. A new intervention has been pioneered in America called 'iLS' (Integrated Listening Systems) which seeks to improve auditory and sensory integration and processing.

The study will evaluate the effectiveness of the iLS system in an educational setting. This evaluation will include standardized measures directly related to measuring improved sensory processing using the Sensory Processing Measure. A further 10 questions will be added into the SPM specifically asking about attentional control and to examine if changes in sensory processing result in changes of attention. (Vanderbilt Teacher Assessment). The Scan- 3:C test will also be used as a battery of tests which screen and diagnose auditory processing difficulties in children. Pre -and post tests will be used to measure any improvements in auditory and sensory skills. The data will also be compared to teacher observation of a child's ability in the classroom and parent experiences at home.

The intervention will be for 30 sessions (3 times a week). One or two children can be included in each session.

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- Attend Deal Parochial Church of England School, Deal, Kent
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Procedures

Children participating will attend sessions three times a week for half an hour. They will wear headphones through which (treated) classical music is played and will simultaneously perform physical tasks (such as throwing /catching balls and playing games). The children will leave their class and take part in the program on Tuesday, Wednesday and Thursday afternoons. Times will be scheduled to cause minimum disruption to their lessons.

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Dissemination of results

The results will form the basis of a dissertation which Debra Cluff is submitting for an MSc in Psychology at Canterbury University, a journal article and conference poster. Also, summary data and statistics in anonymous form may be shared with other interested schools. Children's personal details will not be included in this. A summary of the findings will be made available to the parents and the school in line with general policy of data sharing with parents by the school.

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Any questions?

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HEADTEACHER'S CONSENT

I give consent for this intervention project to take place in my school (Deal Parochial Church of England Primary School)

Signed ....

Justine Brown
Headteacher Date..

Tables

Table 3. Participant Demographics - Study 1

	Gender	Age	Diagnosis
CHILD 1	M	6	ADHD
CHILD 2	M	6	Speech and Language Disorder
CHILD 3	F	7	Dyslexia, Autism
CHILD 4	F	7	ADHD
CHILD 5	F	9	Dyslexia
CHILD 6	M	9	Dyslexia, Autism
CHILD 7	F	6	Sensory Disorder
CHILD 8	M	6	Autism

Table 4. Participant Demographics - Study 2

	Gender	Age	Diagnosis
CHILD 1	F	9	Dyslexia
CHILD 2	M	9	Dyslexia, Autism
CHILD 3	F	6	Sensory Disorder
CHILD 4	M	6	Autism
CHILD 5	M	7	Autism
CHILD 6	M	7	Developmental Delay
CHILD 7	F	5	Autism ADHD,
CHILD 8	M	5	Sensory Integration Disorder

Table 5.

Individual scores for test subscales.

Raw Scores Home - Study 1

	Waiting control								Intervention															
	Pre- intervention								Pre-intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM					Scan 3:C			SPM				
	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B
P5				12	11	12	16	15				17	15	13	17	18				15	11	13	17	14
P6				26	16	24	18	12				33	30	26	20	17				28	32	31	11	25
P7				30	27	23	27	28				18	26	23	22	32				21	24	24	24	28
P8				25	14	20	23	24				29	18	30	23	26				27	20	29	26	25
P9				13	11	12	15	14				12	9	11	17	15				12	11	11	17	15
P10				12	10	23	20	29				13	11	19	18	25				14	8	15	15	18
P11				19	27	29	23	21				19	25	31	25	22				16	26	23	20	18
P12				20	19	21	26	17				24	26	32	24	19				19	15	19	25	19

Notes. *P- Participant number* *SPM scales: V -Visual* *H- Hearing* *T- Touch* *BA – Body awareness* *B – Balance*

Raw Scores Home - Study 2

	Pre- intervention						Post- intervention					
	Scan 3:C	SPM					Scan 3:C	SPM				
Intervention Group		V	H	T	BA	B		V	H	T	BA	B
P1		24	15	23	34	27		21	18	18	24	22
P2		18	18	22	27	22		33	19	17	33	24
P3		23	13	15	22	21		22	13	15	18	19
P4		18	20	23	29	29		19	15	22	29	21
Control Group												
P5		12	11	12	16	15		17	15	13	17	18
P6		26	16	23	20	12		32	30	26	20	17
P7		30	23	23	27	29		18	26	23	22	32
P8		25	14	20	23	22		29	18	30	23	26

Notes. *P- Participant number* *SPM scales:* *V -Visual* *H- Hearing* *T- Touch* *BA – Body awareness* *B – Balance*

Standardised Scores Home

Study 1

	Waiting control								Intervention															
	Pre- intervention								Pre-intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM					Scan 3:C			SPM				
	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B
P5	8	11	2	50	59	47	60	54	9	8	8	63	66	52	61		9	13	7	59	59	52	61	54
P6	7	8	8	72	67	67	63	47	8	9	6	78	80	71	65		9	10	8	75	80	74	48	72
P7	10	9	1	76	79	68	72	76	9	11	3	64	78	68	65		12	11	8	68	76	68	69	71
P8	13	6	7	71	64	65	68	68	7	6	6	75	69	74	68		8	10	6	74	71	73	71	71
P9	9	9	5	54	59	47	59	54	10	9	6	50	52	40	61		11	10	9	50	56	40	61	57
P10	3	7	6	50	56	68	65	74	12	5	6	54	41	64	63		7	10	11	57	43	57	59	63
P11	14	13	6	65	79	72	68	66	14	7	6	65	77	74	70		14	12	10	61	78	68	65	63
P12	10	9	5	67	70	66	71	61	6	7	5	70	78	75	69		14	10	9	65	66	64	70	64

Notes. *P- Participant number Scan 3:C tests AFG- Auditory Figure Ground FW- Filtered Words CWFR- Competing Words- Free Recall SPM scales: V -Visual H- Hearing T- Touch BA – Body awareness B – Balance*

Study 2

	Pre- intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM				
Intervention Group																
	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B
P1	9	12	10	70	66	68	79	72	11	12	11	68	69	63	69	68
P2	11	12	10	64	69	67	72	68	13	12	14	79	70	61	78	71
P3	11	8	9	69	63	57	67	66	11	10	12	68	63	67	63	64
P4	12	10	7	64	71	68	74	76	11	12	12	65	66	67	74	66
Control Group																
P5	8	11	2	50	59	47	60	54	9	8	8	63	66	52	61	63
P6	7	8	8	72	67	68	65	47	8	9	6	78	80	71	65	61
P7	10	9	1	76	79	68	72	76	9	11	3	64	78	68	67	77
P8	13	6	7	71	64	65	68	68	7	6	6	75	69	74	68	74

Notes. *P- Participant number Scan 3:C tests AFG- Auditory Figure Ground FW- Filtered Words CWFR- Competing Words- Free Recall SPM scales: V -Visual H- Hearing T- Touch BA – Body awareness B – Balance*

Raw Scores School

Study 1

	Waiting control								Intervention															
	Pre- intervention								Pre-intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM					Scan 3:C			SPM				
	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B
P5				10	11	11	11	27				27	10	12	13	15				13	12	11	9	21
P6				15	12	10	12	24				24	12	15	15	15				13	14	13	10	19
P7				10	13	10	10	19				19	13	13	16	12				7	7	11	8	9
P8				21	18	22	18	36				36	13	19	19	20				8	10	11	19	22
P9				10	14	8	11	17				17	17	21	20	22				12	13	17	16	18
P10				14	7	11	10	13				13	11	8	9	13				11	8	10	10	12
P11				11	15	12	12	15				15	14	16	13	13				10	14	16	11	11
P12				12	9	10	16	22				22	19	12	14	18				11	13	12	14	16

Notes. *P- Participant number* *SPM scales:* *V -Visual* *H- Hearing* *T- Touch* *BA – Body awareness* *B – Balance*

Study 2

	Pre- intervention						Post- intervention					
	Scan 3:C	SPM					Scan 3:C	SPM				
Intervention Group		V	H	T	BA	B		V	H	T	BA	B
P1		11	8	8	13	27		8	7	8	44	11
P2		13	15	10	17	24		7	9	8	44	10
P3		15	16	17	21	19		11	17	12	63	15
P4		18	17	14	28	36		16	15	14	68	31
Control Group												
P5		10	11	11	11	17		10	10	12	63	15
P6		15	12	10	12	13		16	12	15	68	15
P7		10	13	10	10	15		23	13	13	65	12
P8		21	18	22	18	22		23	13	19	75	20

Notes. *P- Participant number* *SPM scales:* *V -Visual* *H- Hearing* *T- Touch* *BA – Body awareness* *B – Balance*

Standardised Scores School

Study 1

	Waiting control																Intervention							
	Pre- intervention								Pre-intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM					Scan 3:C			SPM				
	AFG	FW	CW-FR	V	H	T	BA	B	AFG	FW	CW-FR	V	H	T	BA	B	AFG	FW	CW-FR	V	H	T	BA	B
P5	8	11	2	57	61	61	59	63	9	8	8	57	59	63	63	60	9	13	7	59	63	61	54	69
P6	7	8	8	67	63	58	61	56	8	9	6	70	63	68	66	60	9	10	8	75	67	65	57	66
P7	10	9	1	57	65	58	57	60	9	11	3	77	65	65	67	53	12	11	8	68	43	61	51	40
P8	13	6	7	76	75	78	69	70	7	6	6	77	65	75	70	67	8	10	6	74	59	61	70	70
P9	9	9	5	57	67	44	59	61	10	9	6	65	74	78	72	70	11	10	9	50	65	72	67	64
P10	3	7	6	65	43	61	51	61	12	5	6	53	61	44	54	56	7	10	11	57	52	58	57	53
P11	14	13	6	59	61	63	61	60	14	7	6	57	67	87	63	56	14	12	10	61	67	70	59	51
P12	10	9	5	62	56	58	56	69	6	7	5	64	76	63	65	64	14	10	9	65	65	63	58	61

Notes. *P- Participant number Scan 3:C tests AFG- Auditory Figure Ground FW- Filtered Words CWFR- Competing Words- Free Recall SPM scales: V -Visual H- Hearing T- Touch BA – Body awareness B – Balance*

Study 2

	Pre- intervention								Post- intervention							
	Scan 3:C			SPM					Scan 3:C			SPM				
Intervention	AFG	FW	CWFR	V	H	T	BA	B	AFG	FW	CWFR	V	H	T	BA	B
P1	9	12	10	59	52	44	63	74	11	12	11	48	43	44	61	51
P2	11	12	10	64	69	58	68	72	13	12	14	40	56	44	54	47
P3	11	8	9	67	72	72	75	66	11	10	12	59	74	63	68	60
P4	12	10	7	73	74	67	80	80	11	12	12	70	69	68	80	78
Control Group																
P5	8	11	2	57	61	61	59	63	9	8	8	57	59	63	63	60
P6	7	8	8	67	63	58	61	56	8	9	6	70	63	68	66	60
P7	10	9	1	57	65	58	57	60	9	11	3	77	65	65	67	53
P8	13	6	7	76	75	78	69	70	7	6	6	77	65	75	70	67

Notes. *P- Participant number Scan 3:C tests AFG- Auditory Figure Ground FW- Filtered Words CWFR- Competing Words- Free Recall*
SPM scales: V -Visual H- Hearing T- Touch BA – Body awareness B – Balance

Table 6. Effect size Study 2

	Base-line Mean	Time 1 Mean	Z score	Effect size N=16	Time 1 Mean	Time 2 Mean	Z score	Effect Size N=16
Scan 3:C (8 in group)	7.75	7.63	.254	.06	7.63	9.92	-.254	-.064
SPM (8 in group)								
Raw Home	19.6	21.25	-1.33	-.33	21.25	19.5	-1.36	-.34
Raw School	14.22	14.75	.56	-.09	65.12	63.82	-1.26	.46
Standardised Home	64.1	65.12	-.34	.14	14.75	12.55	1.82	-.32
Standardised School	61.13	64.98	-1.82	-.46	21.25	19.5	-1.36	-.34