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Therapeutic Listening® and Bilateral Coordination in Typically Developing Children

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Abstract

This study examined the effects of a 15-minute Therapeutic Listening Quickshift® series intervention on 8-10 year-old typically developing children. A convenience sample was used for 8 participants in Marin County, California. Participants were randomly assigned to either the Therapeutic Listening® intervention or white noise control intervention. All participants participated in a pretest to establish a baseline of bilateral coordination abilities. Participants then listened to 15-minutes of the Therapeutic Listening® or white noise interventions. Following this intervention period, participants then participated in a posttest identical to the pretest. Movement assessment measures from the bilateral coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition* (BOT-2) and the Quick Neurological Screening (Backwards Tandem Walk and Rapid Forearm Rotation) were used for the pretest and posttest measures. Following the 15-minute interventions, one item from the BOT-2, Tapping Feet and Fingers, trended towards improvement in the Therapeutic Listening® group. Results of the Backwards Tandem Walk indicated a significant improvement in bilateral coordination in the Therapeutic Listening® group compared to the white noise control group. Positive findings from this study, though limited, give researchers an indication that the effects of Therapeutic Listening Quickshift® series on bilateral coordination are trending towards significance. This pilot study will be continued into 2015 for researchers to assess a greater amount of subjects, add to this current data, and ultimately increase the statistical power of findings.

Introduction

Sound-based therapy interventions are commonly used in occupational therapy treatment in a variety of settings and for a variety of purposes, including improving both mental and physical abilities, despite limited evidence-based research suggesting their effectiveness. Currently, only low-level research has been published to support the use of sound-based therapy interventions in a variety of health care settings. Healthcare professionals using sound-based therapy include psychologists, speech-language pathologists and occupational therapists (Gee, Devine, Werth, & Phan, 2013).

The purpose of this research study was to generate high level evidence to support the effectiveness of a specific sound-based intervention, Therapeutic Listening®'s Quickshift series, on the bilateral motor coordination of 8-10 year old typically developing children. The proposed outcome of this study was to utilize findings to support future studies in investigating the use of sound-based therapy interventions for populations that could benefit from them, particularly children with sensory processing disorders.

Literature Review

This literature review will explore the evolution of sound-based therapies and the global effect listening has on an individual. This will provide a background for the theory behind utilizing the Therapeutic Listening® program on children to promote bilateral coordination skills. The first section will examine the history of music and the healing effects music can provide for the listener. Different sound-based interventions that have been utilized in the medical field will be explored, including the Therapeutic Listening® program's Quickshift series, which is the focus of this study. The second section will focus on the neurological processes of listening through the examination of alpha brainwave activation. This will include a look into the Sensory Integration theory and the sensory systems that influence listening. These systems will be important to consider in the following section. The next section will explore the relationship between movement and sound, which is the theory behind using the sound-based interventions, including Therapeutic Listening®. Following the examination of this relationship, bilateral coordination and its effects on typically developing children compared to children with various processing conditions will be explored. The functional implications of dysfunctions in bilateral coordination will be presented, including the long-term effects of these dysfunctions. Finally, the importance of therapists utilizing interventions that can delineate the impacts of motor coordination disorders will be explained, leading to the need for further research on the effectiveness of the Therapeutic Listening®'s Quickshift program on bilateral coordination in children.

History of Music/Sound in Healing

In preliterate cultures, music played an important role in healing. The belief that music held magical power led to the use of rhythms, songs, and chants as healing tools. In South Africa, prehistoric cave paintings from 20,000-15,000 BCE illustrate the use of musical instruments in local tribal healing rituals (Brooke, 2006). In ancient Egypt, (3000 B.C.), chant therapies were used by high priest-physicians. During the Renaissance period, advocates of music therapy believed physicians should have musical training in order to prescribe curative musical treatments. It wasn't until the 1800's that medicine became more science based and music was no longer considered to be an appropriate therapeutic approach.

Although the use of music and sound in medical treatment ended, scientific studies continued to be done on music and its effects on human behavior and physiological response. With the coming of World War II, music made its way back into the world of medicine. By

1946, most VA hospitals used music in some way during treatment of veterans (Brooke, 2006). With the increased use of music therapy, universities in the United States began offering degrees in music therapy. Though music was once again recognized as a form of therapy, the physiological role that music played in traditional medicine was still unclear. Nevertheless, it was agreed that music therapy had a place in the role of healing (Brooke, 2006).

In 1993, researchers from the University of California at Irvine (UCI) showed a positive relationship between the music of Mozart and spatial learning in college students and children (Campbell, 1997). The term "Mozart Effect" gained expansive recognition. This term, however, had originally been coined years before by Alfred Tomatis, a leading sound therapy researcher. In the 1950's Tomatis found that the rhythms, melodies, and high frequencies of Mozart's music stimulated the brain's creative and motivational regions, producing calmness, improving spatial perception, and increasing expression (Campbell, 1997; Thompson & Andrews, 1999). Decades after Tomatis' discovery, the announcement of the "Mozart Effect" by the UCI researchers influenced public schools to begin playing Mozart as background music while hospitals piped the recordings into neonatal units. The world began embracing music as a method of enhancing the brain's power (Campbell, 1997).

With the advancement of technology in the last 20 years, brain imaging and brain wave recordings allow researchers to study the physiologic effect of music and sound on the brain. Research has shown that music/sound can physiologically stimulate cognitive, affective and sensorimotor processes (Thaut, 2005). Music and sound-based therapy is now considered to be a valid tool by healthcare professionals around the world.

Conditions Treated by Sound-Based Therapy

From early intervention to end-stage dementia, the use of sound-based therapy is growing. Focus areas for sound-based therapy include neurodevelopmental maturation of motor, speech and language skills, sensory integration of sensory processing disorders and autism spectrum disorders, neurological rehabilitation for traumatic brain injury and cerebral vascular accident, and gait training for neurodegenerative disorders (Thompson & Andrews, 1999).

Types of Sound-Based Therapies

The Tomatis Method (TM). In the 1950s, French physician, Alfred Tomatis, used his training in the field of ears, nose and throat (ENT) to create a sound-based treatment for listening disorders. Tomatis believed he could positively affect auditory processing and vestibular control by training people to listen more effectively. Using sound stimulation, he hypothesized the brain would be able to create new neural pathways, developing an integrated structure between sound and sensory data that may have been damaged or dysfunctional. With the integration enhanced, the brain would be better able to process sensory data (Thompson & Andrews, 1999; Gee, Devine, Werth & Phan, 2013). In the Tomatis Method, an electronic ear connected to media players and filters allows high frequencies of at least 16,000 – 20,000 Hz to be accentuated. Through filtered recordings, the ear is trained to become a better receptor and energy generator for the brain. In addition, the right ear may be trained to become the dominant ear, leading to enhanced processing of speech in the left hemisphere of the brain (Thompson & Andrews, 1999). At present, TM is recognized worldwide as a sound-based therapy tool, although evidence-based research on its efficacy has shown mixed results (Thompson & Andrews, 1999).

Auditory Integration Training (AIT). A colleague of Tomatis, Dr. Guy Berard, proposed his own theory and therapy method. Berard believed that hearing was equal to behavior. He developed a machine called the Audiokinetron and began to focus on the field of autism (Thompson & Andrews, 1999). In AIT, an audiogram is obtained and compared to sound sensitivities and behaviors of the individual. Computer modified music is then listened to for a determined amount of time. Proponents of AIT report improvement in attention, auditory processing, irritability, lethargy, auditory comprehension and expressive language (AAP, 1998). However again, there is a lack of evidence-based research showing efficacy of this sound-based therapy (Thompson & Andrews, 1999; APA, 1998).

SAMONAS Sound Therapy. Developed by Ingo Steinbech, SAMONAS (Spectral Activated Music of Optimal Natural Structure) is an extension of the Tomatis Method. Headphones are used to listen to filtered music, voice and nature sounds, however the sound therapy is played on normal CD players (Thompson & Andrews, 1999; Sinha, 2011). Children with developmental disorders that include auditory processing dysfunction are among the groups SAMONAS targets for therapy. As before, there is a lack of clinical evidence of efficacy, but anecdotal reports claim positive results (Kurtz, 2008; Sinha, 2011).

Neurologic Music Therapy (NMT). Neurologic Music Therapy (NMT) is comprised of three techniques: Rhythmic Auditory Stimulation (RAS), Vocal Intonation Therapy (VIT), and Musical Neglect Training (MIT). These techniques target sensorimotor, speech and language and cognitive functioning. Applications of the techniques may be used for gait training, speech intelligibility and amelioration of visual neglect (de l'Etoile, 2010). The biomedical science of music has been the focus of research since the early 1990s. The positive results of efficacy have led to the use of standardized treatment techniques in the field of NMT (Thaut, 2005).

Integrated Listening Systems (ILS). This therapeutic technique combines sound stimulation with balance, movement and visual motor activities. The goal is to improve function in auditory, visual, vestibular, motor, cognitive and emotional areas. This is a program that can be purchased by parents for use in the home. Evidence of efficacy has been shown on a limited basis, but is mostly anecdotal at this point (May-Benson, Carley, Szklut, & Schoen, 2013).

Therapeutic Listening®. Therapeutic Listening®, (Frick, 2009) developed by Sheila Frick, a pediatric occupational therapist, is a sound-based intervention that uses a series of electronically modified music CDs and specialized headphones to trigger the self-organizing capacities of the nervous system. According to Frick and Young (2009), by using electronically modified music, Therapeutic Listening® uses different sound frequencies to trigger attention and body movement. Within the Therapeutic Listening® program, there are five different series (the Modulated Series, the Fine Tuning Series, the Spatial Enhancement Series, the Gearshifters Series, and the Quickshift Series), each with its own type of electronic modification and expected outcomes. The Modulated Series is typically the first series used by clients. The focus of this series is orienting and attending to sound in order to increase engagement and interaction with the environment, and to improve overall sensory modulation. The Fine Tuning Series follows the Modulated Series and enables listeners to tune in and attend to important detail in their auditory environment. The Spatial Enhancement Series improves spatial and temporal awareness by using bidirectional microphones to simulate listeners' physical presence in their spatial surroundings. The Gearshifters Series facilitates a state of relaxed focus and helps children with difficult transitions. This series also promotes hemispheric synchronization, which facilitates bilateral coordination. The Quickshift Series is an extension of the Gearshifter series and provides the same outcomes in a shorter amount of time. Quickshift differs from the other TL series because the intervention lasts only 20 minutes and has an immediate impact on function, whereas the other series require the listening to occur in daily, multiple 20-30 minute sessions over a period of weeks. According to Frick, Quickshift can help children with difficult transitions, sensory modulation and regulation, and bilateral integration by helping synchronize the two hemispheres of the brain (Frick & Young). The Quickshift Series is the focus of this study and will be discussed more thoroughly later in this literature review. The following sections will discuss the current research behind Therapeutic Listening®.

The Effectiveness of Therapeutic Listening®

Therapeutic Listening® is often used as an intervention in sensory integration clinics, school systems, and other pediatric settings despite limited research on its effectiveness. The existing research, although limited, suggests that Therapeutic Listening® has positive outcomes related to childhood occupations. In 2007, Hall and Case-Smith studied the effectiveness of an 8-week Therapeutic Listening® intervention combined with a sensory diet for children, compared to a sensory diet alone. The interventions were implemented on children with sensory processing disorders and were conducted in each child's home by his or her parents. Findings showed the combined Therapeutic Listening® and sensory diet intervention improved behaviors related to sensory processing, visual motor integration, and handwriting more than a sensory diet alone. Another study, conducted by Bazyk in 2010, showed statistically significant improvements in fine motor, visual motor, social, and language skills in 3-6 year old children with developmental disabilities who were given a Therapeutic Listening® intervention from six weeks to four months depending on their need. This study, however, did not show significant improvement in sensory processing. Aside from these two studies, case studies describing the effectiveness of Therapeutic Listening® also show positive results from the intervention, however, most of the case studies involved a Therapeutic Listening® intervention combined with other occupational therapy interventions, such as sensory diets, postural and coordination activities, and home programs. Due to the implementation of combined interventions, it is unclear which interventions could have caused the improvements (What is Therapeutic Listening ®, 2014).

Quickshift: How it works. As mentioned above, Therapeutic Listening® is offered in a variety of series, each evoking a different type of response. The Quickshift series is designed to entrain brainwaves to a neutral alpha frequency, which is the optimal state for relaxed alertness and spontaneous contemplation. It also produces a binaural beat by shifting the frequency between the right and left channels (Frick & Young, 2009). The Quickshift series causes a binaural beat by presenting two sounds of similar frequencies into each ear through the specialized headphones. The right and left hemispheres of the brain begin to produce similar brainwave patterns and rhythmic synchronization occurs, producing a sensation of a third sound; the binaural beat. Binaural beats and alpha waves are explained in more detail in the following sections.

Binaural Beats

Binaural beats are defined as an auditory brainstem phenomenon that has the ability to alter physiological and cognitive processes involving brainwave entrainment (Goodin, 2012). The phenomenon of “normal hearing” is not specifically occurring when humans listen to binaural beats. Humans cannot consciously entrain the rhythms at which binaural beats are administered. The normal auditory range for humans is 20-20,000 Hz and occurs when sound vibrations enter the auditory canal and pass into the cochlea. Binaural beats resonate at a frequency below 20 Hz. The cortical entrainment of binaural beats occurs through interaction within the superior olivary nuclei located in the pons of the brainstem to create pure tones that entrain cortical processes that foster inter-hemispheric connection (Foster, 1990).

Alpha Waves

The superior olivary nuclei are considered to be the major site of auditory convergence from the left and right ears within the brain. The superior olivary nuclei receive these auditory projections from the anteroventral cochlear nucleus. The binaural beats frequency can be adjusted to produce alpha waves in therapeutic practice by offsetting different sounds. (Goodin, 2012). Alpha waves are defined as a brain wave phase of alert calm inattention. Alpha waves are most consistently produced when an individual is awake in a restful state with their eyes closed. The constant production of alpha waves creates a mental state of calm focus (Foster, 1990). This mental state is highly sought after in clinical practice involving children with sensory processing disorders who often might be experiencing symptoms of anxiety, restlessness, frustration and incoordination that affect their occupational performance in various activities (Foster, 1990).

Alpha wave production is strongly associated with the visual system. Alpha waves can be produced through an occulomotor pattern alone (Goodin, 2012). Although alpha is most easily produced by having the individual keep his or her eyes closed or having the individual attend to a non-attention stimulus such as a blinking light flickering at a range within the alpha frequency, therapeutic practices commonly involve combining an activity while administering binaural beats in order to keep the individual functioning as they would on a regular basis outside of therapy. By having an individual in a calm, alert state while staying active, the process of listening to the binaural beats before an activity can lead to smoother motor coordination, increased attention, or decreased anxiety (Goodin, 2012).

Sensory Integration and Sound

Therapeutic Listening® is based on the theory of sensory integration. Sensory integration, developed by Jean Ayres in 1972, is defined as “the ability to organize sensory information for use” (p. 1). Ayres developed this theory based on neural plasticity of the brain, or the ability of the brain to be influenced by ongoing activity by forming new neural connections. She felt that because of neural plasticity, the body’s ability to integrate all the senses could be improved through controlling the sensory systems input to activate brain mechanisms (Ayres, 1972). The following section will discuss the connection of sensory integration to sound-based interventions, such as Therapeutic Listening®. For a more thorough description of sensory integration, see the section titled “Theoretical Framework”.

Auditory stimulation and the vestibular system. Ayres focused on six sensory systems (visual, auditory, olfactory, tactile, proprioceptive, and vestibular) and how input into each of these systems affected certain functions. Ayres noted that auditory stimuli are among those most frequently found to elicit a response in convergent neurons found throughout the brain (Ayres, 1972). She also hypothesized that because the auditory system evolved out of the vestibular system, a close relationship between the two is possible (Ayres, 1972). According to Frick and Young (2009), because of this strong connection between the auditory system and brain activity, sound is a powerful way to access the nervous system and cause changes. They suggest that being exposed to auditory input can improve many areas of function, including areas that are influenced by not only auditory but also vestibular systems. These areas include arousal, attention, focus, vigilance, concentration, orientation to space and time, and motor learning.

Motor Learning

The concept of "motor learning" has been extensively researched over the past thirty years (Barral, Debû, & Rival, 2006; Bo & Lee, 2013; Crowe & Horak, 1988; Willoughby & Polatajko, 1995). Motor learning refers to the process of acquiring new motor skills through practice and experience (Bo & Lee, 2013). This process leads to fairly permanent changes in an individual's behavior and ability to actively respond to life experiences. By expanding this repertoire of skills, motor learning not only helps an individual adapt to his or her environment, but also enables us to engage in activities of everyday life.

Bunker (1991) found that motor learning development follows a clear timeline; most basic movement patterns are formed between ages two to ten. This development is driven by the natural, physical development that occurs through these years, as children gain confidence in exploring themselves and the environment they are surrounded by. From a neurological perspective, motor performance typically improves during this time period as a result of the neural pathways being created between both sides of the brain (Barral et al., 2006). Although motor skill development most prominently occurs during this time, motor learning can occur across the lifespan, as evident through motor skill acquisition following stroke and traumatic brain injury (Hurt, Rice, & McIntosh, 1998; Schauer & Mautriz, 2003).

There are four factors that influence this developmental process of motor learning, including 1) the stages of learning, 2) the type of task, 3) feedback, and 4) practice (Poole, 1991). One of the most influential motor learning variables is feedback, which can be intrinsic or extrinsic (Poole, 1991). Intrinsic feedback is the perception of sensory information we receive from our body's sensory systems, including our muscles, skin, and visual, auditory, and vestibular systems. Extrinsic feedback is information we receive from the environment that enhances the intrinsic feedback we process, such as from an occupational therapist. In comparing the differences between adults and children in the motor learning process, it has been found that children perform better when receiving feedback as opposed to adults performing that same task (Sullivan, Kantak, & Burtner, 2008).

The significance of feedback and the auditory system on motor learning and control is measured on a variety of motor assessments for children. The Movement Assessment Battery for Children (MABC) is used to assess motor and postural control. Researchers determined that children with some level of hearing loss show marked decreases in motor performance tasks, which was exemplified in the absence of visual stimuli (Livingstone & McPhillips, 2011). Additionally, researchers investigating the development of bilateral coordination (discussed in the following sections) have determined an association with vestibular and proprioceptive functioning by using the bilateral integration and sequencing component of the Sensory Integration and Praxis Test (Mailloux et al., 2011). Crowe and Horak (1988) also studied this effect of motor proficiency in children with vestibular system deficits and hearing impairments. They found that when children had hearing impairments and irregular vestibular system function, they also had difficulty with balance. To further examine this association between the auditory, vestibular, and motor systems, researchers have utilized auditory interventions through various medical treatment strategies.

The Movement and Sound Relationship

As previously discussed, auditory interventions have been used in various treatment settings to facilitate changes in a diverse range of areas, including motor control (Bernatzky, Bernatzky, Hesse, Staffen, & Ladurner, 2004; Hausdorff et al., 2007; Hurt et al., 1998; McIntosh, Brown, Rice, & Thaut, 1997; Pelton, Johannsen, Chen, & Wing, 2010). Using functional MRI (fMRI) scans, researchers found three distinct regions of the brain associated with movement exhibit activation when listening to musical rhythms (Chen, Penhune, & Zatorre, 2008), demonstrating the connection between movement and sound. Bernatzky et al. (2004) found that individuals with Parkinson's disease improved the precision of arm movements after listening to stimulating music, further suggesting an association between the auditory and motor systems. Similar research using sound to increase motor performance supports this relationship between sound and movement, suggesting the use of sound and music can be a viable method for increasing bilateral motor skills (Ford, Wagenaar, & Newell, 2007; McIntosh et al., 1997; Schauer & Mautriz, 2003). Bilateral motor skills, also known as bilateral coordination, have recently become the focus of research based on motor learning and how the movement and sound relationship affects this learning.

Bilateral Coordination

Bilateral coordination is considered an increasingly challenging task through which motor skill acquisition can be determined. Bilateral coordination, defined as the congruent use of the right and left limbs in a coordinated fashion, is a more complex motor skill that begins to prominently emerge by age six (Huh, Williams, & Burke, 1998). Bilateral coordination is unconsciously used for everyday activities such as buttoning a shirt or catching a cup as it falls to the ground. Researchers have found that bilateral coordination abilities have far-reaching implications on cognitive skills such as reading, writing, math, and organizational skills (Isenhower et al., 2012).

Developmental coordination disorder. When an individual demonstrates a lower level of motor coordination during activities of daily living that cannot be attributed to another medical, intellectual, or developmental condition, this individual may be classified as having a developmental coordination disorder (American Psychiatric Association, 2000). Although children with developmental coordination disorder (DCD) have comparable intellectual abilities compared with typically developing children, they historically been labeled as “clumsy and awkward”, as they easily bump into others and display uncoordinated movements. Evidence suggests that this deficiency of motor abilities is due to less efficient and inconsistent motor learning and control strategies (Huh et al., 1998).

Children with DCD may have subtle central nervous system (CNS) dysfunction, evident by an inability to organize and perform voluntary movement patterns, including bilateral coordination (Huh et al., 1998). This may be exhibited through impairments in coordination or balance, movement confines in catching and throwing a ball, and participation limitations in playing with others. Along with DCD, other conditions can greatly impact bilateral coordination abilities in children.

Conditions that result in bilateral coordination dysfunction. Bilateral coordination is the result of successful CNS processing, organization of information, and execution for voluntary movements. Any condition that disrupts this process may result in bilateral coordination dysfunction. This was first hypothesized by Jean Ayers, who positioned that impairments in sensory processing ultimately leads to functional impacts in motor control, as well as behavior, attention, and learning (Roley, Mailloux, Miller-Kuhanek, & Glennon, 2007). Following Ayers research, other studies have investigated various conditions that affect an individual’s motor performance, including bilateral coordination skills.

In comparing bilateral motor coordination in adolescents with and without learning disabilities (Cermak, Trimble, Coryell, & Drake, 1990), researchers found that adolescents with learning disabilities performed significantly poorer on motor tasks compared with adolescents without learning disabilities, as measured by items from the Bilateral Coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency. These findings suggest that children and adolescents with learning disabilities have increased difficulties that extend beyond academic abilities. Similar results of impairments in bilateral coordination have been found in children with Autism Spectrum Disorders (ASD).

As children with ASD have difficulty processing incoming information, they may also experience some degree of motor performance dysfunction (Provost, Lopez, & Heimerl, 2007). Isenhower et al. (2012) investigated this motor performance dysfunction by comparing the abilities of typically developing children and children with ASD to accurately complete a drumming task, highlighting 'bimanual rhythmic coordination' of the two groups. The children with ASD were less able to maintain the rhythmic drumming pattern, showing more difficulty with the drumstick that was held in hand while the opposite hand hit the drum with the drumstick simultaneously. Furthermore, children with ASD showed a varying degree of tempo by speeding up or slowing down within a trial, whereas typically developing children were better able to sustain a self-paced tempo (Isenhower et al., 2012). These findings highlight not only the bilateral coordination deficits children experience with conditions such as learning disabilities, ASD, and DCD, but also some functional implications of such deficits.

Implications for deficits in Bilateral Coordination

Bilateral coordination and motor control are fundamental tools children use everyday to learn, play, and interact with peers and the environment around them. When the brain is not able to successfully create these movement patterns, the child may be negatively affected in areas beyond motor control (Cermak et al., 1990; Huh et al., 1998; Rodger et al., 2003; Willoughby & Polatajko, 1995). Research conducted by Tal-Saban et al. (2012) found that DCD negatively impacts academic performance in skills such as handwriting, and non-academic skills that require coordination, organization and planning such as time management. These motor impacts result in lowered self-esteem due to lowered self-perceived efficacy (Tal-Saban, Zarka, Grotto, Ornoy, & Parush, 2012). Families of children with DCD may also experience the repercussions of these motor impairments in their daily lives. Research suggests that having a child with DCD may impact daily family routines due to the extra time and verbal feedback needed for the child to complete daily routines, such as getting dressed or tying shoelaces (Summers, Larkin, & Dewey, 2008).

Ultimately, the biggest effect of bilateral coordination dysfunction is on the quality of life of the individual experiencing the dysfunction. Young adults who have lived with the disorder recall that their childhood experiences resulted in social isolation, frustration, and avoidance of activities that emphasized physical coordination such as sports or certain types of jobs (Missiuna, Moll, King, Stewart, & Macdonald, 2008). When investigating overall quality of life satisfaction in emerging adults with and without DCD, the adults with DCD reported significantly lower satisfaction in areas of general satisfaction, feelings, school/coursework, leisure activities, and social relationships compared with typical adults without DCD (Hill, Brown, & Sophia Sorgardt, 2011).

Conclusion

To help children and adults with bilateral coordination dysfunctions, occupational therapists need to focus their treatment on improving life satisfaction and engagement in activities of daily living for this population. In order to achieve this, occupational therapists need to utilize interventions that target the underlying factors leading to dysfunction. As previously discussed, research suggests there is a connection between the auditory, vestibular, and motor systems as evidenced by the movement and sound relationship (Bernatzky et al., 2004), (Hausdorff et al., 2007), (Hurt et al., 1998), (McIntosh et al., 1997), (Pelton et al., 2010). As it has been well established that rhythmic auditory therapies can have beneficial results on motor performance (Cauraugh et al., 2010; Hayden et al., 2009; Hurt et al., 1998), there is the need for further evidence that supports the effects of Therapeutic Listening® on bilateral coordination.

Statement of Purpose

Currently, there is a lack of evidence-based research in the area of sound-based therapy in occupational therapy. Despite this lack of evidence, occupational therapists are using sound-based therapy as an intervention based solely on the positive results found in level IV and very limited level II research. Therapeutic Listening®'s Quickshift program is designed to improve certain skill sets, including bilateral coordination in one 15-minute intervention. Because of the large population of children with sensory processing disorders who could potentially benefit from this sound-based therapy, the purpose of this study is to establish evidence of the effectiveness of the Therapeutic Listening® Quickshift on bilateral motor coordination in typically developing 8-10 year old children. By investigating Therapeutic Listening®'s effects on typically developing children, further studies can utilize these findings to conduct research on the populations that may benefit from this sound-based intervention. Thus, our research question is:

1. Does the Therapeutic Listening®'s Quickshift program improve performance in bilateral motor coordination on various motor tasks in typically developing 8-10 year old children?

Theoretical Framework

Sensory Integration Defined

Our study on the effect of Therapeutic Listening® on bilateral coordination follows the sensory integration frame of reference. Sensory integrative theory best describes the relationship between sensory systems including auditory and vestibular and their connection to bilateral motor output. In this section we will be covering what sensory integration is, the sensory abilities that lead to proper integration, the theoretical postulates, the research efficacy of sensory integration and the relationship between sensory integration and Therapeutic Listening®.

The theory of sensory integration was created by A. Jean Ayres. Ayres was trained as both an occupational therapist and an educational psychologist at the University of Southern California where she graduated in 1961. Ayres describes sensory integration as "the unconscious neurological process that organizes sensory information to enable use of the body effectively within the environment" (Ayres, 2005, p. 5). Sensory integrative dysfunction occurs when the brain is not processing sensory information adequately, which manifests as problems with learning and behavior.

Sensory integration can be likened to the brain directing the flow of traffic smoothly by locating, organizing and sorting different sensations. There are three main constructs important to sensory integrative theory. The first is that in order for learning to occur, the ability to process sensations from movement and the environment is necessary to plan and organize behavior. The second construct states that an individual who is not able to process sensations will face challenges in producing appropriate actions to stimuli and this may interfere with behavior and learning. The last construct states that if enhanced stimulation is provided as part of a meaningful activity, it will improve the ability to process sensory information and yield an adaptive response, creating a positive outcome on learning and behavior (Ayres, 2005). An adaptive response is described as, "A purposeful, goal-directed response to a sensory experience" (Ayres, 2005, p. 7). An adaptive response is the brain's way of organizing sensory information, and is based on the brain's ability to use neuroplasticity to change. Neuroplasticity is constantly changing the brain's organizational structure throughout the lifespan (Ayres, 2005).

A child's main way of learning through adaptive response will manifest in play. A child will come across a challenge and develop a way to respond appropriately to it. A therapist working under the framework of sensory integration will help to create a "just right challenge" for a child to meet in order for the child to form an adaptive response. Ayres assumes the CNS is plastic and the adaptive response creates a more organized neural pathway for processing sensory information (Ayres, 2005).

Sensory integration is focused on the somatosensory and vestibular systems working in unison to contribute information about the environment and movement within the environment. The first sensory system to develop in utero, and also the largest, is the somatosensory system. The somatosensory system is composed of the tactile and proprioceptive systems. The tactile system perceives sensations such as pain, temperature, vibration and pressure. Proprioception is defined as knowing where your body parts are located in space. Lastly the vestibular system is a key piece of sensory integration. The vestibular system plays an important role in maintaining balance. Sensory receptors located in the inner ear provide information about movement and gravity (Biel & Peske, 2005). The vestibular system is also connected to the cochlea. Decreases in vestibular function could result in issues surrounding language and auditory processing. The vestibular system also supports development of laterality and can impact bilateral coordination (Bundy, Lane & Murray, 2002).

Sensory Integrative Abilities According to Ayres

Ayres defines five main sensory integrative abilities that lead to effective sensory integration. These abilities are praxis, sensory discrimination, sensory modulation, postular-ocular control, and bilateral integration and sequencing. Praxis is defined as the ability to motor plan. Ayres defined praxis as a process that includes three main steps. Step one is ideation, which includes visualizing what should happen motorically. Step two is motor planning, which shows the active problem solving process in which the individual's body movements reflect the individual's internal sensory awareness of his or her body interacting with the environment. Step three involves executing the planned movement and receiving feedback regarding whether the movement was successful or not (Williamson, Anzalone & Hanft, 2000). Praxis is strongly tied to cerebellar functioning for sequencing in bilateral movement and balance (Ayres, 2005).

Another sensory integrative ability is sensory discrimination. Sensory discrimination is the ability to discern all the different senses from each other. An individual who is unable to discriminate different sensory systems will perceive sensations in a jumbled disorganized manner (Ayres, 2005).

Sensory modulation is the ability to sort out relevant stimuli perceived by the nervous system. By modulating the amount of sensory information coming into the brain an individual can attend solely to relevant stimuli. Ayres describes sensory modulation as the nervous system's method of organizing itself by sorting through inhibitory and excitatory messages. According to Ayres, modulation is "the brain's regulation of its own activity". In this statement Ayres is referring to modulation as the brains ability to increase or decrease the amount of neural activity perceived from a stimulus so the body can remain balanced and organized. The vestibular system plays a key role in sensory modulation by regulating activity from the brainstem and cerebellum (Ayres, 2005). The four most common type of modulation disorders are gravitational insecurity, sensory defensiveness, aversive responses to movement, and under-responsiveness to sensations. These types vary depending on which sensory systems are being affected (Bundy, Lane & Murray, 2000).

Postular-occular control integrates the vestibular, proprioceptive, and visual systems in order to stabilize the trunk and proximal joints during motor action. It is the foundation for development of both gross and fine motor skill because it allows us to have a stable base of support for functional activities and skills, including the ability to use our eyes to get information from our environment.

Bilateral integration and sequencing integrates the vestibular, visual, and proprioceptive systems in order to coordinate both sides of the body to complete a task. This skill requires good postural control and the development of laterality (Ayres, 2005).

Theoretical Postulates of Sensory Integration

In order to provide optimal growth and development using a sensory integration frame of reference, there are 10 theoretical postulates that should be followed when conducting a sensory integration intervention (Kimball, 2009). These postulates are as follows: 1) an optimal state of arousal is needed for an adaptive response to occur, 2) sensory integration occurs during adaptive responses, 3) more than one sensory system is needed to reach an optimal state of arousal, 4) adapted responses must be appropriate for a child's developmental level, 5) a "just right challenge" will promote growth and development, 6) sensory modulation difficulties contribute to deficits in other abilities, 7) a child needs to be self-directed for sensory integration to occur, 8) adaptive responses are elicited when activities facilitate all of the sensory integrative abilities, 9) intervention is directed at underlying deficits in sensory integrative abilities, not at a specific skill or behavior, and 10) achieving increasingly complex adaptive responses will produce evident changes in abilities such as self-regulation, self-esteem, social participation, and academic performance (Kramer). Together, these 10 postulates form the foundation of sensory integration treatment. If all of these postulates are followed in practice, the child receiving treatment can potentially improve his or her occupational performance in multiple areas due to the effective intervention.

Research on the Efficacy of Sensory Integration

Sensory integration is a heavily researched occupational therapy frame of reference, with studies examining a broad range of its characteristics. Three key areas of sensory integration research include 1) understanding the neuro-physiological foundation of the framework, 2) validating the components of the various sensory integrative disorders, and 3) determining the efficacy of sensory integration intervention. Many studies have been conducted on the efficacy of sensory integration intervention, however, its effectiveness is still controversial (May-Benson & Koomar, 2010). Current research studies of sensory integration efficacy have limitations, such as small sample sizes and lack of controls for extraneous variables. Also, some studies do not show proper implementation of sensory integration techniques. In some cases, researchers have attempted to duplicate sensory integration interventions without a licensed and trained sensory integration therapist, which can drastically skew the intervention outcomes (May-Benson & Koomar). Even fewer studies show evidence of following the 10 postulates that guide sensory integration intervention.

In 2010, May-Benson and Koomar attempted a systematic review of 27 research studies spanning over 37 years for the effectiveness of sensory integration intervention. In their review of level I through IV studies, they found sensory integration intervention to have a trend of positive results, especially when compared to no treatment. However, the authors reported many limitations to the studies, for instance, all of the studies had some methodological problems such as lacking independent evaluators, not reporting the qualifications of the treating therapists, or using inappropriate evaluators from psychology students to a research assistant not related to the field of occupational therapy. Other limitations included issues with sample sizes, dosing of the intervention, and characteristics of the sample population.

Another study aimed to assess the validity of sensory integration outcomes research in regard to fidelity of the research. Fidelity is achieved if the intervention under study is faithful to the theoretical and clinical guidelines of its underlying framework. The authors sought to find whether current studies are adequately following sensory integration framework to achieve their results. They looked at the characteristics of environment of the intervention, equipment used, therapist competence, and core process elements such as providing a just right challenge, collaborating with the child on activity choices, maximizing success, and supporting optimal arousal. Though 94% of the 34 studies described the professional background of the interveners, only 65% described the type of therapeutic equipment, 26% described collaborating with the child on activity choices, 12% described supporting optimal arousal, and only 9% described maximizing a child's experiencing of success. These results show that much of the research on the effectiveness of sensory integration does not fully address the key components of sensory integration intervention and therefore fidelity has not been reached. Without fidelity, outcomes of sensory integration effectiveness studies cannot adequately be presented (Parham et al., 2007).

In 2011 in response to the need for fidelity in research, a group of occupational therapists created a reliable and valid fidelity measure for use in research on sensory integration intervention. The measure contains a 5-point scale to indicate the strength of fidelity for the structure and process elements of the interventions being tested. The efficacy of sensory integration is heavily researched but with varying results. With the new fidelity measure in place, further research may show more accurate results when researching the effectiveness of sensory integration intervention (Parham et al., 2011).

The Relationship Between Sensory Integration and Therapeutic Listening®

Therapeutic Listening®, though not a true form of sensory integration when used in isolation, is aligned with the sensory integration theoretical framework because it follows many of the key concepts of Ayres' research findings. Ayres acknowledged a connection between processing sound and sensory integration, and she understood that the auditory system could provide a powerful avenue into sensory integrative therapy (Ayres, 1972). Though Ayres did not directly study the effect of sound on motor control, her findings do suggest a strong connection between the auditory and vestibular systems due to their anatomical and physiological similarities. Auditory receptors in our inner ear evolved out of gravity receptors. Ayres notes that this connection still exists. With their sensory inputs traveling through a single nerve to the brain stem, the two systems continuously "talk" to one another (Ayres, 1979). Also, the specific Therapeutic Listening® intervention of improving bilateral coordination can be linked back to Ayres comments on the bilaterality of the auditory and vestibular systems. According to Ayres, bilateral integration involves good communication between the right and left sides of the body (Ayres, 1972). Therefore, the assumption can be made that the bilateral auditory input via binaural beats can potentially produce the necessary communication by synchronizing the two hemispheres of the brain. The creators of Therapeutic Listening® used these concepts as basis of their intervention, however, Therapeutic Listening® cannot be considered a primary form of sensory integration treatment since it lacks some of the main components of the sensory integration framework, such as, using a using a child-directed approach and providing sensory opportunities in multiple sensory systems (tactile, vestibular, and proprioceptive) (Kimball, 2009). Therapeutic Listening® can be considered a complementary intervention to use in conjunction with a sensory diet or sensory integration intervention that follows all core theoretical postulates of the sensory integration framework (Frick, 2009).

Sensory integration best describes the relationship between Therapeutic Listening® and bilateral coordination. Although Therapeutic Listening® is not considered a sensory integration treatment, it is complements sensory integration by illustrating how by activating one sensory system, a motor response is produced. The framework of sensory integration describes the process of how sensory information enters and is organized in the brain. All the sensory systems supply us with information about the surrounding environment and our body's physical structure. The abilities to motor plan for smooth coordination depend on how sensory information in the brain is interpreted. The theory of sensory integration provides the basis for understanding how Therapeutic Listening® targets and syncs the auditory system with the vestibular system to produce smooth, coordinated bilateral movement. This reflects how the framework of sensory integration can be utilized in Therapeutic Listening® to benefit children with bilateral coordination issues.

Methodology

Design

The influence of Therapeutic Listening® Quickshifts on bilateral coordination was studied using a double-blind, randomized control, pretest-posttest experimental design. Scores from the bilateral coordination subtest of Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, (BOT-2BS), Sensory Performance Analysis (SPA) subtests and clinical observations of bilateral coordination assessed each participant's bilateral motor performance before and after intervention with either a Therapeutic Listening® Quickshift or a control condition (i.e. white noise). Further, a Likert scale was used to understand each participant's individualized experience of the intervention (Portney & Watkins, 2009).

Participants

The target population for this study was typically developing eight to ten year old children. We strived for a 1:1 ratio of males and females, as there is no known ratio difference in sensory integration disorders. Participants were recruited from St. Anselm Elementary School in San Anselmo, California and from occupational therapy students or faculty at Dominican University of California. The inclusion criterion for participation was a) eight to ten year olds, and b) English-speaking. The exclusion criteria were no presenting cognitive, mental or physical disabilities, including sensory processing dysfunction. In order to determine this, a brief questionnaire was sent to parents of potential participants during recruitment (Appendix A). Restrictions were not made based on gender, race, ethnicity or socioeconomic status.

Legal and Ethical Considerations

A formal proposal of the research study was sent to the Internal Review Board for the Protection of Human Subjects of Dominican University prior to contact with all study participants. A participation agreement (Appendix B) was signed by St. Anselm School to confirm permission to conduct our research at their location and to recruit participants. All eligible participants at this school were invited to participate in the study through an informational flyer and email sent by the school. Families interested in having their child participate responded directly to the research team via email or a potential participation form. For the purpose of obtaining informed consent for this research study, the researchers had parents/caregivers of the subjects sign a proxy consent form to agree to include their child in the study. There was also a section for parents/caregivers to sign for permission for researchers to videotape the assessment portions of the session. Formal, written consent to participate was gained through permission and confidentiality forms from the parents prior to participation and verbal assent was gained from the participating child at the time of assessment. Permission for using school facilities was obtained from the principal of St. Anselm School. A formal letter was sent to obtain permission for use of school facilities for the research sessions at each site. All assessments and surveys were included with the IRB application. The BOT-2 and SPA are commercially available assessments. Both assessments are owned by the Occupational Therapy department of Dominican University of California and copyrighted forms were purchased.

In order to protect participants' personal information and identities throughout the study, participants were assigned a number. All forms, except an initial contact form, contained only the participant ID number and no other identifying information. All hard copies of informational forms and raw data were stored in a locked cabinet in the faculty advisor's research office on the Dominican University of California campus. Only the research advisor had access to the keys to this cabinet and room. Study information was stored electronically on the home computer of one of the four researchers of this study and the computer of the faculty advisor. Both computers were password protected and on secured networks. All electronic data was de-identified. Video records of each participant were stored in the locked cabinet and will be saved in order for the successive research study to reference during their data analysis. When using children as research subjects, there must be a high level of sensitivity ensuring confidentiality for all participants, which is what this research group has aimed to achieve.

Instruments

The quantitative and qualitative analysis of bilateral coordination was measured through two assessments, clinical observations, likert scale and video analysis. A brief background questionnaire completed by parents was used to determine if their child matched all requirements for the study.

Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition.* Bilateral coordination subtest of the BOT-2 was used. We used the bilateral coordination subtest of the BOT-2 (BOT-2BS) which includes 7 tasks: touching nose with index fingers-eyes closed, jumping jacks, jumping in place-same sides synchronized, jumping in place-opposite sides synchronized, pivoting thumbs and index fingers, tapping feet and fingers-same side synchronized, and tapping feet and fingers-opposite sides synchronized. There is a possible score of 24 on this subtest. The child was given the opportunity for two trials. These scores were converted to standard scores. The BOT-2 is a widely used standardized measure of motor function with good reliability. Internal consistency reliability of the bilateral coordination subtests for ages 8, 9, and 10 are 0.76, 0.87 and 0.79 with standard errors of measurement 2.25, 1.69 and 2.02. Test-retest reliability correlation coefficients are 0.65 and 0.71 for ages 8-12. Inter-rater reliability coefficients are 0.98 and 0.98 for ages 4-21 (Bruininks & Bruininks, 2005).

Sensorimotor Performance Analysis. We used two components of the SPA: the Belly Crawl and the Log Roll. The Belly Crawl task requires motor planning and reciprocal coordination of upper and lower extremities. The Log Roll task requires motor planning competence. The tasks are scored from 1 to 5, 1 representing poor and 5 representing optimal performance. In typical 8 to 12 year-olds, a score of 5 is considered appropriate. In a preliminary assessment of reliability of the SPA, test-retest reliability ranged from .89 to .97.

Inter-rater reliability was .76. Validity studies, other than those done by the author, do not currently exist on this assessment, although use of the SPA in clinical settings has shown apparent accuracy in assessing current status, known as concurrent validity (Richter & Montgomery, 1995).

Clinical observations. Three additional clinical observation tasks to test bilateral coordination were administered. Two of these tasks were quick neurological screens: 1) rapid forearm rotation, and 2) backwards tandem walking. Rapid Forearm Rotation is accomplished by alternating palms-up and palms-down movements while seated. This task was timed for the amount of movements completed in 10 seconds to provide a quantitative measure. Backwards Tandem Walk was accomplished by placing feet on a line and walking toe to heel, backwards. This task was timed for the amount of steps taken in 10 seconds to provide a quantitative measure. The Infinity Walk Observational Assessment (IWOA) was the third clinical observation used.

The IWOA is accomplished by focusing on a target while walking in a figure eight pattern around two specifically placed cones in a distance of ten feet. This task was timed for the amount of figure eight patterns completed in 20 seconds to provide a quantitative measure.

Likert Scale. We used a pretest, posttest likert scale survey. This helped to determine the participant's mood state regarding the Therapeutic Listening®/white noise intervention. A posttest survey of how the activity made the participant feel was also given. A Likert scale is a popular, simple method of assessing a subjective experience (Portney & Watkins, 2009). We used two scales, one anchored by the words "very sad" and "very happy" for the pretest, posttest mood state, and the other "very bored" and "very excited" for how the participant felt regarding the activity overall. The scores ranged from 1 to 5, 1 representing "very sad" and 5 representing "very happy". Similarly, 1 represented "very bored" and 5 represented "very excited". By using two likert scales we were able to assess different but related aspects of the intervention. In addition, all assessments and observations were videotaped and reviewed for qualitative data.

Review of videotapes of participant's performances were controlled for and determined interrater reliability. When reviewing the videotapes, researchers rescored the assessments and compared that score to the 'live' score. The differences between the two scores were compared, which controlled for accuracy and reliability of test scoring. To control for test-retest reliability, one researcher completed the entire test administration process of the pretest and posttest on the same participant. Tester reliability was improved by practice administering the tests and scoring pilot subjects as a group.

Data Collection

Procedures. Prior consent to participate was obtained from each participant's parent prior to research sessions. Children were oriented to the study after this consent and their assent had been obtained. Once consent and assent had been obtained, participants were individually brought into a quiet classroom where all the procedures of the study took place. The participants were tested at similar times of the day, in the afternoon after school. One researcher was in charge of determining intervention condition type, noting this type on the coded information sheet and administering the condition type to the participant during that part of the research procedure. The researcher responsible for administering the assessments had no knowledge of the intervention condition type given to the participant. This researcher also scored the assessment. The other researchers observing the assessment also had no knowledge of the intervention condition type. The participant was not informed of the effect of music versus white noise and so had no knowledge of possible effect. This allowed for a double blind study.

Upon entering the classroom, each participant completed the pretest with one researcher to establish a baseline of abilities in the different assessments. The pretest assessment included the BOT-2 bilateral coordination subtest, two tasks from the SPA, three clinical observation tasks and two Likert surveys. The pretest took approximately 10-15 minutes to complete. Once the pretest was completed, participants were randomly assigned a pair of headphones to wear for the intervention phase. These headphones either played the Therapeutic Listening® Quickshift music or white noise. The Therapeutic Listening® Quickshift music was used as the experimental condition. The control group listened to white noise which was a constant non-soothing background static. This was the control condition. Participants were assigned a condition type based on the roll of dice. To assure equal condition types among and between genders, once a participant had been randomly assigned a type, the next participant of the same gender was assigned the other condition type. The opposite gender was also assigned condition type by the roll of a dice. This allowed for a randomized, balanced study.

At the start of the intervention phase, the participant was instructed to be seated, and to perform a quiet activity such as looking at a picture book or coloring while listening to music/white noise in his/her headphones. The intervention took 15 minutes. After the 15 minutes had ended, measures of the pretest were re-administered by the researcher to determine a posttest score. The posttest took approximately 7-12 minutes to complete. The anticipated total time required of the participant was 32-42 minutes.

Data Analysis

A mixed model, repeated measures ANOVA with t-tests for follow-up was utilized to determine if there were differences in performance between the group following intervention or control conditions. The significance level was set at $p = 0.05$. This analytic approach allowed researchers to appropriately assess the outcomes of the experimental and control groups. Qualitative data came from coded data retrieved from video analysis of the assessments. This video analysis was coded with numbers. Analysis of the quantitative and qualitative data was used to determine efficacy of the Therapeutic Listening® Quickshift intervention.

Results

Eight typical 8-10 year old children, five males and three females, from Marin County, California completed the study. Four participants received the intervention and listened to Therapeutic Listening® Quickshift music. Four participants were in the control group and listened to white noise. All participants completed pretest and posttest assessments. All participants gave their assent to be videotaped at the time of the assessments.

A series of repeated measures ANOVAs were conducted to compare the mean differences in pretest and posttest scores on all key measures and items between the Therapeutic Listening® group and the white noise group. As this was an exploratory pilot study, further pre-planned t-tests were conducted to compare the pretest to posttest scores for the experimental group only to identify items or scales that were sensitive to the intervention.

BOT-2 Bilateral Subtest (BOT-2BS) and Item Scores

The repeated measures ANOVA revealed no significant differences in the mean pretest and posttest BOT-2BS scaled-combined scores (SSC) for either the Therapeutic Listening® (TL) or White Noise (WN) group $F(1,7) = .574$, $p = .477$, *partial eta squared* =.087

As seen in Table 1, both the control and experimental groups scored the maximum possible points in the pretest for four of the BOT-2BS test items. However, there was no such ceiling effect for Item 4 (Jumping in Place - Opposite Sides Synchronized), Item 5 (Pivoting Thumbs and Index Fingers) and Item 7 (Tapping Feet and Fingers - Opposite Sides

Synchronized) in the pretest of either group. For the purposes of this pilot study, researchers were interested in further investigating these three items from the BOT-2BS to assess for possible utility. For Items 4 and 5, there was no significant difference in the mean pretest and posttest scores for either group. (Respectively, $F(4)=1.5$, $p=.267$, *partial eta squared*=.455, $F(5)=1.589$, $p=.254$, *partial eta squared*=.266). The group comparison in the ANOVA for Item 7 demonstrated a trend towards significance ($F(7)=3.0$, $p=.134$, *partial eta squared*=.33). A paired t-test trended towards a significant difference between pretest and posttest BOT-2BS Item 7 scores for the TL group ($t(1,3)=2.53$, $p=.085$) but not the WN group ($t(1,3)=1.414$, $p=.252$).

Quick Neurological Screening Scores

Repeated measures ANOVAs were conducted to compare scores on two test items from the Quick Neurological Screening: the Rapid Forearm Rotation (RFR) and the Backward Tandem Walk (BTW). A repeated measures ANOVA indicated that the mean posttest BTW scores showed a trend to be significantly higher than the pretest scores for both groups ($F=3.6$, $p=.107$, *partial eta squared*=.375). A paired t-test comparing the BTW scores revealed a significant difference between pre and posttest scores for the TL group ($t=11.00$, $p=.002$). The TL group had a significantly higher mean score (mean =12.5, see Table 1) following the intervention. A repeated measures ANOVA indicated that the mean posttest RFR scores showed a trend to be significantly higher than the pretest scores for both groups ($F=4.4$, $p=.081$, *partial eta squared*= .424). However, further analysis revealed that this was due to improvement in the control group. There was no significant improvement in the mean score from pretest to posttest in the experimental group ($t=.6$, $p=.591$).

Sensori-Motor Performance Analysis (SPA) Scores

Repeated measures ANOVAs were conducted to compare scores on two test items from the SPA: the Belly Crawl and the Log Roll. The repeated measures ANOVA revealed no significant differences or trends toward significance in mean pretest and posttest Log Roll scores for either the TL or the WN group. Of the 9 subtests of the Belly Crawl, only one (lateral trunk rotation) trended toward significance differences between pretest and posttest scores (F=3.86, p=.097, *partial eta squared*=.391). A follow-up t-test conducted on the pretest and posttest of the experimental group showed no significance (t=1, p=.391).

Infinity Walk Observational Assessment Scores

A repeated measures ANOVA revealed no significant differences or trends toward significance in mean pretest and posttest scores on the Infinity Walk Observational Assessment for either the TL or WN group.

Discussion

Overall, the findings from this study give researchers an indication that this research should be continued in the future. If more subjects had taken part and the statistical power of the study was greater, overall findings of no significance would merit a termination of the study. However, as this is a pilot study, further researchers will continue on to assess a greater amount of subjects for the purpose of adding to this current data in order to increase statistical power of findings.

The results of the Backward Tandem Walk indicated a significant improvement in bilateral coordination in the TL experimental group compared to the white noise control group (see figure 1). Given the small power of our study, the Backwards Tandem Walk is an assessment that already displays significance. When combined with qualitative matters with a larger sample size, this could become the most sensitive measure to assess bilateral coordination.

Researchers found that many of the assessment measures were not sensitive enough to detect change for typically developing children. Closer examination of the means table (Table 1) will reveal that ceiling was reached on four out of the seven items on the BOT-2 bilateral coordination subtest on pretest. However, Items 4, 5, and 7 did not reach ceiling at the pretest for either groups. After further investigation of these items, Item 7, Tapping Feet and Fingers Opposite Sides, was the only measure that trended towards improvement in the Therapeutic Listening® experimental group (see figure 2). Because this item had an effect size of .33, we can expect it to move towards significance with more subjects. This indicates that these specific tasks are more sensitive measures than the other items on this subtest and should be further investigated during the continuation of this study.

Upon initial analysis the Rapid Forearm Movement showed a trend toward significance. However, the significance was not present in the pretest posttest experimental group but in the control group possibly due to a significant practice effect. The large variance in scores (see Table 1) may be attributed to the difficulties in scoring this assessment. Despite a thorough analysis of each subject's performance on video by all researchers, there was a lot of variability in performance, including extraneous movements that were difficult to assess and interpret.

Three assessments performed (Rapid Forearm Rotation, Backward Tandem Walk and Infinity Walk) concentrated on quantitative movement scores, although they also had qualitative scoring components. For the purpose of this study, the quantitative scores were the focus. For example, the Backward Tandem Walk was scored by the number of steps taken, however, irregular hand position, inability to maintain accurate toe to heel walk, pigeon-toed or bent knee stance, poor balance difficulty managing backward walk, inability to maintain midline walk, or involuntary/spastic body movements are a part of the qualitative measurement that could be used for more in-depth analysis. The qualitative video analysis of these movement patterns may be a more sensitive measure to detect possible change in quality of movement. Therefore, the videos of each participant should be analyzed in the continuation of this study. The Infinity Walk and Rapid Forearm Rotation were also scored using quantitative data, but qualitative measures exist for both of them. By using a more in-depth qualitative assessment of movement patterns, these particular assessments could add another level of sensitivity to this study.

An examination of the means showed that Belly Crawl Item 8 (lateral trunk movement) trended towards significance although no difference in experimental pretest posttest group was shown upon further analysis. When analyzing video for qualitative scoring of the SPA, it was noted that participants made some improvement, but not necessarily enough to jump from a 1 to 3 or 3 to 5, as scoring allows. If gradations were used to allow scoring to include 2 and 4, these improvements could be noted and results may show more sensitivity to the qualitative assessments of the SPA.

An interesting effect noted among the participants in the white noise condition was a decrease in posttest scores in Log Roll and Belly Crawl. Although researchers can only conjecture that while sound-based therapy, including the Therapeutic Listening® Quickshift, can be organizing to the brain, a noise such as the static white noise used as the control intervention could be disorganizing, potentially leading to a decrease in scores in the posttest.

The double blind design was a bit of a challenge. The second participant unknowingly revealed his study condition to the researchers. From that time forward, the researchers informed the participants that their study condition was not to be shared with any researchers other than the researcher in control of the headphones. The remainder of the study was successfully a double blind design.

Conclusion

Presently, there is a lack of evidence-based research in the area of sound-based therapy utilized in occupational therapy treatment sessions. Regardless of this lack of evidence on its effectiveness, occupational therapists continue to use sound-based therapy as an intervention strategy within treatment . One particular intervention, Therapeutic Listening®, is commonly used in pediatric OT settings with a variety of conditions and diagnoses. The purpose of this study was to generate evidence-based research to determine the effectiveness of the Therapeutic Listening® Quickshift series on bilateral coordination in typically developing 8-10 year children. It was intended that data from this research will be able to provide more evidence to support how sound-based therapy can be applied to children with sensory processing disorders who could benefit from sound-based occupational therapy intervention. The use of typically developing children was to establish baselines among healthy children before assessing more vulnerable populations of children.

Our initial research question was, “Does the Therapeutic Listening®’s Quickshift program improve performance in bilateral motor coordination on various motor tasks in typically developing 8-10 year old children?” The results of this study demonstrated that a significant change in bilateral coordination did in fact occur in one assessment item, the Backward Tandem Walk, as a result of Therapeutic Listening® Quickshift intervention. One assessment item, Contralateral Finger Tapping, trended towards significance. However, the other assessments did not show significance. Likely conclusions for these results are that this study was underpowered and the tools used to assess items were not sensitive enough to detect change in bilateral coordination. Therefore, we recommend this study be continued at Dominican University of California during the 2015 school year in order to assess more subjects and increase the statistical power of these positive, preliminary findings. These authors encourage further video analysis of the data collected in 2014 to allow for more sensitivity of the assessments used and more in-depth data to be collected. Future researchers should also consider using qualitative data in order to increase the sensitivity of the assessment tools. They should also consider using a larger sample size to show more accurate results. Additionally, using a group with known difficulties in bilateral coordination, such as using a sample of children with sensory processing difficulties, may be more appropriate for testing the effectiveness of Therapeutic Listening® Quickshift. Through the continuation of this study, researchers hope to provide further evidence on the effectiveness of this intervention's use within the field of occupational therapy.

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Appendix A

Background Questionnaire

Date: _______ ID#: 02

Age of Child: ________ Date of Birth: ________________ Grade in School: ___________

Relationship to participant of person completing this form: ___________________________

Child's Ethnic Background (please circle one):

African American
American Indian or Alaskan Native
Asian or Pacific Islander
Hispanic
White
Other or unknown

Birth History: any complications or difficulties prior to or during birth of the child: Prematurity, fetal distress, long labor, caesarian birth, oxygen required, prolonged hospitalization, injuries or birth defects? ____

____

Developmental Milestones: Did the participant achieve the following milestones more or less on time (typically), or were they delayed

	Age when child first:
Smiled	
Made eye contact	
Walked	
Colored or Drew	
Said first word	
Spoke in phrases	
Caught a ball	
Rode a bike	
Read words	
Wrote name	

Questionnaire on Health and Development

Please list all medication taken during the last month:

____

Please describe any chronic or reoccurring illnesses:

____

Does the child have a history of any of the following (please describe if answer is yes):

Vision or hearing problems YES NO_____________________________________

Physical Limitations YES NO_____________________________________

Learning/Developmental Disorder YES NO_____________________________________

Significant Injury or Trauma YES NO_____________________________________

Seizures or Neurological Difficulties YES NO_____________________________________

Participation in Special Education YES NO_____________________________________

Family/Living Situation

Mother/Caregiver's Occupation: ____________________________________

Highest level of education (please circle one)

- Less than 7th grade
- Completed 8th or 9th grade
- Completed 10th or 11th grade
- Graduated from high school
- Some college or specialized training
- Graduated from four year college or university
- Has graduate or degree

Father/Caregiver's Occupation: _____________________________________

Highest level of education (please circle one)

- Less than 7th grade
- Completed 8th or 9th grade
- Completed 10th or 11th grade
- Graduated from high school
- Some college or specialized training
- Graduated from four year college or university
- Has graduate or degree Dominican University of California Research

Appendix B

PROXY CONSENT FORM FOR RESEARCH PARTICIPATION

DOMINICAN UNIVERSITY of CALIFORNIA

Purpose and Background

Shanee Ben-Haim, Cassie DeBonis, Jane Schwartz, and Amy Smith-Schwartz, graduate students, and Dr. Julia Wilbarger, Professor, of the Department of Occupational Therapy at Dominican University of California, are doing a research study on the effectiveness of the Therapeutic Listening program for improving bilateral coordination in typically developing children. Currently, there is a lack of evidence-based research in the area of sound-based therapies used in occupational therapy settings. Despite this lack of evidence, occupational therapists are using sound-based therapies as interventions based on case study information. There is a large population of children with sensory processing disorders who could potentially benefit from sound-based therapies, including Therapeutic Listening. In order for future studies to examine this population, research must first be completed on typically developing children. Therefore, the researchers are interested in establishing evidence of the effectiveness of the Therapeutic Listening Quickshift program on bilateral motor coordination in typically developing 8-10 year old children.
My child is being asked to participate because s/he is a typically developing 8-10 year old attending the after school program where this research study will be taking place

Procedures
If I agree to allow my child to be in this study, the following will happen:

1. I will complete a consent form allowing my child to participate in this research study
2. My child will participate in a pre-test of movement assessments before they listen to the Therapeutic Listening Quickshift or the control noise (white noise). This will take approximately 10-15 minutes.
3. After the pre-test, my child will listen to the Therapeutic Listening Quickshift or the control noise for 20 minutes. During this time, they will be engaging in free play with coloring books or toys.
4. After the 20 minutes is finished, my child will participate in a post-test of the same exact same
movement assessments to determine if they increased their scores from the pre-test to the post-test. This will take approximately 10-15 minutes
5. The researchers will observe my child through the entirety of the 40-50 minutes, while also videotaping them for further data analysis purposes.
6. I will be allowed to stay and attend if my child participates, but am not required to be in attendance during my child's participation.

Risks and/or discomforts
1. My child may become uncomfortable or upset during the 45-minute free-play period. My child may experience discomfort by being isolated from peers during the 45 minute assessment, discomfort from listening to adapted music, decreased self-esteem from not being able to complete the assessments and my child may be at a minimal fall risk while completing coordination assessments. If this happens, the researchers will attempt to comfort my child. If my child continues to be upset, the researches will return my child to me in the waiting room and notify me of this occurrence.

2. Study records will be kept as confidential as is possible. No individual identities will be used in any reports or publications resulting from the study. All personal references and identifying information will be eliminated when the data are transcribed, and all subjects will be identified by numerical code only, thereby assuring confidentiality regarding the subject's responses. The master list for these codes will be kept by Dr. Wilbarger in a locked file, separate from the transcripts. Only the researchers and their faculty advisor will see coded transcripts. One year after the completion of the research, all written and recorded materials will be destroyed.

Benefits
There will be no direct benefit to me in this study. My child may benefit from participating in this study if he/she is randomly assigned to the Therapeutic Listening Quickshift group. The anticipated benefit of this study may be improved bilateral motor coordination skills.

Costs/Financial Considerations
There will be no costs to me or to my child as a result of taking part in this study.

Payment/Reimbursement
My child will receive a toy prize for participation in this study. I will not be reimbursed for my child's participation in this study.

Questions
I have talked to Ms. Ben-Haim, Ms. DeBonis, Ms. Schwartz, and Ms. Smith-Schwartz about this study and have had my questions answered. If I have further questions about the study, I may call Ms. Smith-Schwartz at (707) 849-7491 or Dr. Wilbarger at (415) 257-0125. If I have any questions or comments about participation in this study, I should first talk with the researchers. If for some reason I do not wish to do this, I may contact the Dominican University of California Institutional Review Board for the Protection of Human Subjects (IRBPHS), which is concerned with protection of volunteers in research projects. I may reach the IRBPHS Office by calling (415) 482-3547 and leaving a voicemail message, or FAX at (415) 257-0165, or by writing to IRBPHS, Office of Associate Vice President for Academic Affairs, Dominican University of California, 50 Acacia Avenue, San Rafael, CA 94901.

Consent
I have been given a copy of this consent form, signed and dated, to keep.
PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to have my child be in this study, or to withdraw my child from it at any point. My decision as to whether or not to have my child participate in this study will have no influence on my child's present or future status as a patient in my pediatrician's office.
My signature below indicates that I agree to allow my child to participate in this study.

____________________________ ______________________
Signature of Subject's Parent/Guardian Date

____________________________ ______________________
Signature of Person Obtaining Consent Date
(Model letter adapted from USF IRPHS Handbook)

Table 1

Comparison of Means on Measures by Experimental and Control Pretest Posttest Groups

Measure	Experimental pretest Mean	Experimental pretest SD	Experimental posttest Mean	Experimental posttest SD	Control pretest Mean	Control pretest SD	Control posttest Mean	Control posttest SD
BOT 1	4.00	0.000	4.00	0.000	4.00	0.000	4.00	0.000
BOT 2	4.25	1.500	5.00	0.000	5.00	0.000	4.00	0.000
BOT 3	4.50	1.000	4.50	1.000	5.00	0.000	5.00	0.000
BOT 4	2.75	2.630	4.25	0.957	3.75	1.500	4.75	0.500
BOT 5	4.50	4.203	6.00	2.708	2.00	2.449	4.25	3.775
BOT 6	10.00	0.000	9.50	1.000	10.00	0.000	10.00	0.000
BOT 7	2.50	3.317	6.50	4.726	7.00	4.243	8.00	4.000
BTW	9.75	2.630	12.50	2.380	11.25	1.500	12.50	1.732
RFR	13.50	4.123	14.25	4.646	14.00	4.546	18.00	3.367
F8W	3.13	1.031	3.38	0.750	2.50	1.000	3.13	0.250
BC1	4.50	1.000	4.50	1.000	5.00	0.000	5.00	0.000
BC2	2.50	1.915	2.50	1.915	3.00	1.633	2.00	2.000
BC3	4.00	2.000	3.00	2.309	3.00	1.633	3.00	1.633
BC4	2.50	1.000	3.00	1.633	3.00	1.633	2.50	1.000
BC5	4.00	1.155	4.00	1.155	4.00	2.000	3.50	1.915
BC6	5.00	0.000	5.00	0.000	5.00	0.000	5.00	0.000
BC7	4.00	2.000	4.00	2.000	5.00	0.000	4.50	1.000
BC8	2.00	1.155	2.50	1.915	4.00	1.155	3.00	0.000
BC9	2.50	1.915	2.00	2.000	3.00	1.633	2.50	1.000

LR1	5.00	0.000	5.00	0.000	5.00	0.000	4.50	1.000
LR2	4.00	1.155	3.50	1.000	4.00	1.155	4.50	1.000
LR3	4.50	1.000	4.50	1.000	4.00	1.155	3.50	1.000
LR4	4.00	2.000	3.00	2.309	3.00	2.309	3.50	1.915
LR5	5.00	0.000	5.00	0.000	5.00	0.000	5.00	0.000
LR6	5.00	0.000	5.00	0.000	5.00	0.000	5.00	0.000
LR7	4.50	1.000	4.00	2.000	5.00	0.000	4.50	1.000
LR8	5.00	0.000	5.00	0.000	5.00	0.000	5.00	0.000

Figure 1

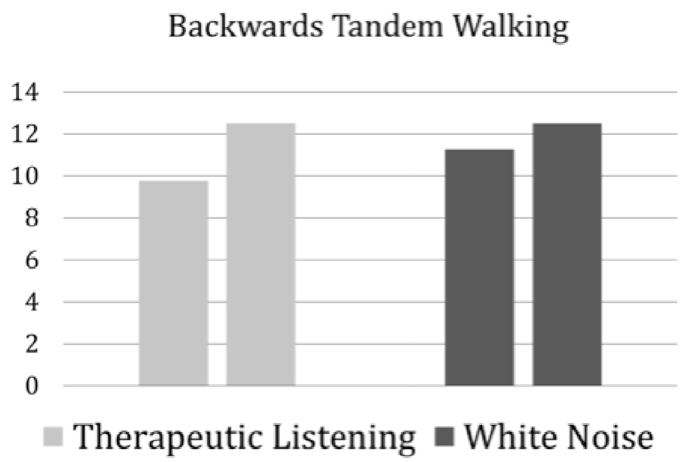

Figure 2