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The Effects of Therapeutic Listening on Bilateral Coordination

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This project was written under the direction and supervision of the candidates' faculty advisor and approved by the chair of the Master's program. This project has been presented to and accepted by the faculty of the Occupational Therapy department in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy. The content and research methodologies presented in this work represent that of the candidates alone.

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Table of Contents

Abstract

Therapeutic Listening® is an intervention increasingly used by occupational therapists despite the lack of supporting evidence in current literature. Therapeutic Listening® is a sound-based treatment developed by Sheila Frick, OTR/L, rooted in sensory integration. The purpose of this continuation study was to compare the quality of bilateral movement in typically developing children after either listening to Therapeutic Listening® Bilateral Coordination Quick Shift or listening to white noise. This study used a randomized control pretest-posttest experimental design to analyze posture, smooth and continuous movement, effort, precision, and arm/leg movements. Specific items were further analyzed after eliminating those with a strong ceiling effect and focusing on items that approached significance in the previous study. Results showed the Quickshift series to have a moderate effect on qualitative movements during bilateral tasks by improving smoothness and rhythmicity. Overall, when compared to the white noise group the intervention group showed a greater improvement in bilateral coordination. Limitations of this study include a low statistical power, and a high ceiling effect. However, despite these limitations the Quickshift series shows promise as an intervention to improve bilateral coordination as this study, together with the standardized tests from the previous study show a trending effect of Therapeutic Listening® on bilateral coordination.

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Introduction

Therapeutic Listening® is a sound based therapy intervention, used in conjunction with sensory integration, with several proposed benefits such as greater performance in sensory processing and motor coordination. Therapeutic Listening® is increasingly used by occupational therapists despite the lack of supporting evidence in current literature. To date, there are only a few published studies examining Therapeutic Listening®. A previous Dominican University of California capstone study attempted to determine the effect of Therapeutic Listening® Quickshift on bilateral coordination as measured by several standardized assessments (Arora, Smiley, Liang & Ramirez, 2015). The test scores did not significantly change following listening to Therapeutic Listening ® Quickshift. In the previous studies, the quantifiable results did not reflect the observations of an improved quality of movement following Therapeutic Listening® intervention (Ben-Haim, Debonis, Schwartz, & Smith-Schwartz, 2015; Arora et al., 2015). Because the quantifiable results did not reflect the qualitative results, the effectiveness of the Therapeutic Listening® on quality of movement was not appropriately represented in current research (Ben-Haim et al., 2015; Arora et al., 2015). The purpose of our research study is to continue to examine the effects of Therapeutic Listening® Quickshift on bilateral coordination. Videotapes from the previous study will be re-examined using a measure of the quality of motor behavior in response to Therapeutic Listening® Quickshift. The goal of this study is to answer the research question: For typically developing children, is the Therapeutic Listening® Bilateral Quickshift, when compared with white noise, more effective in improving bilateral coordination as measured by the quality of movement during bilateral tasks?

Literature Review

The following literature review will explore the effect of sound therapy on the bilateral coordination of children and movement measurements. A background for the theory guiding Therapeutic Listening® will be discussed, along with the potential benefits for a child's bilateral movement. Additionally, bilateral coordination, the relationship between sound and movement, and specific assessment tools will be addressed. The analysis of current measures will lead to the need for further research on how the quality of bilateral movement can be assessed through the use of Therapeutic Listening® Quickshift.

Overview of SI and SPD

A.Jean Ayres, Ph.D, OTR, an occupational therapist and developmental psychologist, formulated the sensory integration (SI) theory in the 1960's. Ayres developed this theory to better understand and guide intervention for children with sensory integrative dysfunction or developmental disorders. SI theory guides both assessment and intervention with people who have sensory integrative and processing dysfunction that adversely impacts function, occupational performance, and participation. Ayres' work inspired the development of related sensory-based interventions for individuals with sensory processing dysfunctions/disorders (SPD) (Schell, Gillen, & Scaffa, 2014). In particular, Therapeutic Listening® is an intervention designed to use sound to help individual with a range of sensory or motor dysfunction. Therapeutic Listening® utilizes the organized rhythm of sound patterns in music to trigger self-organizing capabilities of the nervous system (What is Therapeutic Listening®, 2015). Through the use of the rhythmic sound patterns, Therapeutic Listening® as an intervention can be used to improve a child's motor movement.

History of Sound Based Interventions

Sound based interventions originated from Alfred Tomatis, a French otolaryngologist, who theorized that listening to certain sound frequencies would create new neural pathways in the brain in which compensated for dysfunctional brain pathways and improve function (Gee, Devine, Werth, & Phan, 2013). In the mid-1900s, Tomatis developed electronically altered music and established the technique to use it to treat adults and children with conditions such as Autism, attention deficit disorders, and learning disabilities (Hall & Case-Smith, 2007). His work led to the development of several other sound-based interventions, such as the Tomatis Method, Therapeutic Listening®, and The Listening Program (Gee, et al., 2013). The various sound-based interventions modify music as a part of treatment and differ in the duration and frequency sounds used. Some differ in the particular music used from individual to individual (Gee et al., 2013).

Sound Based Interventions in Occupational Therapy

Sound based interventions are currently used in occupational therapy practice with children to encourage balance and body posture, in addition to cognitive functions such as arousal, attention, and focus. Furthermore, music is used to stimulate motor coordination and awareness of the body in space (Carley, 2013). A survey study conducted by Gee et al. (2013) found that sound-based interventions are being used by pediatric occupational therapists as a supplemental intervention for children with varying medical diagnoses. One of the sound-based interventions being most frequently used by occupational therapists is Therapeutic Listening®.

Therapeutic Listening®. Therapeutic Listening® is a sound-based treatment developed by Sheila Frick, OTR, rooted in sensory integration (Frick & Young, 2009). In Therapeutic Listening® programs, clients listen to music that has been electronically altered (Hall & Case-Smith, 2007). Therapeutic Listening® is composed of various tools, enabling therapists to tailor programs to a client's specific needs (Frick & Young, 2009). With trained practitioner guidance, a program is individualized for each client, and can be carried out by parents and teachers easily (Frick & Young, 2009). Therapeutic Listening® programs are typically used in the home, but can also be used in various settings such as schools and private clinics (Frick & Young, 2009). Occupational therapists often use Therapeutic Listening® as a complement to treatment, as the stimulation seems to prepare the client to participate in purposeful activities (Hall & Case-Smith, 2007).

Types of Therapeutic Listening®. There are four different Therapeutic Listening® programming series: The Modulated Series, The Fine Tuning Series, The Spatial Enhancement Series, and The Gearshifters/Quickshift Series (Frick & Young, 2009). Each of these series modifies music in a unique way to enhance function but also takes advantage of the qualities of the music to facilitate particular functions. For example, music with a strong beat and simple rhythms might enhance bilateral coordination. The Modulated Series is typically where the client begins a Therapeutic Listening® program, and it focuses on orienting to sound and improving overall sensory modulation (Frick & Young, 2009). The Fine Tuning Series is used after the Modulated Series, and it focuses on enabling the listener to attend to important sound-related details in their environment (Frick & Young, 2009). The Spatial Enhancement Series stimulates the listener's physical presence in his spatial surroundings through the use of nature sounds and bidirectional headphones (Frick & Young, 2009). The Gearshifters Series uses binaural beat technology to facilitate a relaxed focus for the listener, which promotes organization, regulation, and receptive learning, and also facilitates bilateral motor coordination (Frick & Young, 2009). The Quickshift series, which also uses binaural beat technology, was created to be used as needed in preparation for therapy or everyday life. The binaural beat technology entrains brain waves to improve bilateral integration, arousal regulation, and sensation modulation (Frick & Young, 2009). The altered music creates a binaural beat by shifting between the frequency between right and left channels (Frick & Young, 2009). Binaural beats are auditory brainstem responses resulting from two different auditory impulses interacting (Foster, 1990). Binaural beats can be adjusted to create alpha waves, which are the brain waves correlated with relaxed consciousness (Foster, 1990). Generally, Quickshifts are 15-22 minutes long and are listened to from beginning to end either using headphones or speakers (Vital Links, 2015). Quickshifts can be used by clients throughout the lifespan with or without particular diagnoses, and have been used as an intervention for various functional or sensorimotor challenges, such as communication, attention, and bilateral integration (An Introduction to Quickshifts, 2015).

Evidence for Therapeutic Listening®. Therapeutic Listening® is widely used as an intervention method by occupational therapists in pediatric settings despite limited research on its effectiveness. Hall and Case-Smith (2007) measured the effectiveness of the Therapeutic Listening® program with a sensory diet on children with sensory processing disorders and visual-motor delays. Participants displayed improvements in behaviors reflective of sensory processing such as attention, peer interaction, listening, self-awareness, communication, sleep patterns, and following directions. Overall, the findings suggest positive outcomes of the use of Therapeutic Listening® in occupational therapy services for elementary school-age children.

Furthermore, in 2010, Bazyk et al. measured the outcomes of the Therapeutic Listening® program in preschool children with developmental disabilities. Statistically significant improvements were noted in several areas, such as fine-motor, visual-motor, non-verbal, language, and social skills. Teachers recognized that the Therapeutic Listening® program positively impacted their preschool students' functional performances as they showed improvements in areas such as printing, understanding verbal directions, and enhancing attention and participation. Results from this study imply that children with disabilities show significant developmental improvements when participating in Therapeutic Listening® programs that are supplemental to traditional occupational therapy services. Research has shown the relationship between sound and movement is profound therefore it is important to be able appropriately measure the effect one can have on the other.

The Previous Study

A recent master's thesis conducted by Arora et al. (2015), explored on the effects of a 15-minute Therapeutic Listening® Quickshift series intervention on seven to eleven year-old typically developing children and found positive results indicating the effects of Therapeutic Listening® Quickshift on bilateral coordination. The participants were randomly assigned to a Therapeutic Listening® Quickshift series intervention or a white noise interventions (Arora et al., 2015). The pretests and posttests consisted of the Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition* (BOT-2) and the Quick Neurological Screening (Backwards Tandem Walk and Rapid Forearm Rotation) (Ben-Haim et al., 2015). The results were improvements in bilateral coordination in one item from the BOT-2 (Tapping Feet and Fingers) and Backwards Tandem Walk following the 15-minute Therapeutic Listening® Quickshift intervention compared to the white noise control group (Ben-Haim et al., 2015; Arora et al., 2015). While there was only a trend in the change of scores on the standardized tests of bilateral coordination, the researchers observed a remarkable change in the quality of bilateral movement. More research is required to identify with detail the positive trending effects of Therapeutic Listening® Quickshift on bilateral movement. The effects of Therapeutic Listening® Quickshift on bilateral movement will be further explored in our study.

Bilateral Coordination

In the previous study, the effect of Therapeutic Listening® on a child's bilateral coordination skills was measured. Therefore, it is important to first understand the concept of bilateral coordination and the effects it can have on a child. According to Huh, Williams, and Burke (1998), bilateral coordination is the ability to move both hands in a cohesive and skillful manner. Children use bilateral coordination for activities such as catching a ball or buttoning a shirt. Activities involving bilateral coordination also require motor planning and sequencing in order to complete the movement. Motor planning or praxis is the "ability to plan and execute skilled or non-habitual motor tasks" (Ayres, 1972). Bilateral coordination development begins in the early stages of a child's life and provides further foundation for more complex motor skills needed to enhance participation and their quality of life.

Development of Bilateral Coordination. As a child grows and matures their skills become more refined, which allows them to complete more complex tasks. The development of bilateral coordination control follows a linear pattern beginning with symmetrical movements, followed by unilateral movements, and finally the development of reciprocal movements (Magalhaes, Koomar, & Cermak, 1989). According to Magalhaes, Koomar, and Cermak (1989), a typically developing six year old child should exhibit mastery of the developmental skills used for bilateral coordination. A child's bilateral motor coordination is usually assessed using various motor tasks such as asking the child to complete a jumping jack, a symmetrical stride jump, or a reciprocal stride jump. Based on the study completed by Magalhaes, Koomar, and Cermak (1989), typically developing children around the age of seven could accurately and consistently complete a jumping jack while a symmetrical jump was not completed consistently until age nine. However, only a few nine year old children could accurately complete the bilateral movement required to complete a reciprocal jump (Magalhaes, Koomar, & Cermak, 1989). Upon assessing a child's motor capabilities, the intrinsic factors of age and gender must be considered. Older children show improved times regardless of motor development which may reflect the developmental changes in a child's central nervous system (CNS) (Magalhaes, Koomar, & Cermak, 1989). The capacity of the CNS to initiate motor movements in response to sensory stimulation is an important aspect of coordinating motor movements (Huh, Williams, & Burke, 1998). However, when comparing the motor outcome of children, gender was not found to be a significant factor influencing the outcome performance ability (Magalhaes, Koomar, & Cermak, 1989). A child's motor ability can be assessed using simple motor tasks such as jumping jacks but their abilities must also be considered within the child's unique developmental and environmental contexts surrounding the task. The acquisition of bilateral motor coordination is vital to a child's development of skills needed across their daily activities. However, when this development is delayed or does not occur there can be lasting effects on the child.

Deficits of Motor Development. The development of motor skills in children is important for successful completion of occupations in school such as using pencils, cutting with scissors, and appropriately holding crayons. However, Ayres (1972) noted that children with poor bilateral coordination tend to also exhibit dyspraxia or vestibular integration disorders impacting their performance ability. The basis of good bilateral coordination is highly dependent upon the integration of both the vestibular and proprioceptive systems as well as the proficiency of the two neuro-hemispheres working together (Magalhaes, Koomar, & Cermak, 1989). The auditory system is closely related with the vestibular and proprioceptive systems in integrating sensations and producing the appropriate motor responses. When the auditory system is not optimally functioning it can result in delayed or atypical motor developmental skills (Sewpersad, 2014). Children who experience auditory processing deficits frequently demonstrate atypical motor development also showed a significantly lower health quality of life (Sewpersad, 2014). Sound is closely related to movement and can greatly influence the development and performance of bilateral motor tasks.

Sound and Movement

Humans are evolutionarily programmed to adjust movement to rhythmic sounds (Hattori, Y., Tomonaga, M., & Matsuzawa, T., 2015). Sound is a phenomenon that humans naturally perceive and more importantly, can naturally benefit from (Hattori et al., 2015). The benefits from sound can include the influence on motor coordination and movement through the interconnectedness of the auditory and vestibular systems.

Sound and Bilateral Coordination. Researchers have facilitated sound-based therapies on unique populations and have found auditory stimulation to improve different types of movement. For example, sound stimulation was tested on children with and without movement difficulties (Utley, A., Nasr, M., & Astill, S., 2010). During the four-week trial, two groups participated in ball activities and a third completed non-ball activities of gymnastics. The sound group incorporated sound-emitting balls while the other used non-sound-emitting balls. The tasks included throwing, catching, and rolling a ball with accuracy. By the end of the trial period, results suggested that the sound group exhibited significant improvement with the ball activities in comparison to the non-sound group and the gymnastics group. Additionally, the authors noted that the superior colliculus, the part of the brain that detects sound and responds to movement, was stimulated in response to the frequency-emitting balls (Utley et al., 2010). The findings by Utley et al. (2010) demonstrate that sound improved ball play abilities in children, which included a level of bilateral coordination to complete.

Sound and Extremity Movement. In another context, a study found that rhythmic sound enhanced upper extremity reaching in clients with hemiplegia (Kim et al., 2014). Researchers stated that rhythmic auditory stimulation (RAS) activates the cerebral cortex, basal ganglia, and cerebellum, and travels through the autonomic nervous system through the brainstem and spinal cord (Kim et al., 2014). Consequently, muscles activate and coordinate as the body syncs with the auditory rhythm. To test RAS, two groups performed reaching tasks while sitting in a chair. One group listened to RAS, and the other served as the control group with no RAS. Results displayed that reaching significantly improved more in the RAS group. The researchers documented that the RAS participants scored a shorter movement time, reduced change in acceleration, increased elbow extension range of motion, exhibited more muscle activation of the triceps, and reduced co-contraction ratio of affected arm (Kim et al., 2014). In short, the RAS group demonstrated more efficient reaches than the control group. The results are relevant to occupational therapy as they can be applied to functional tasks. Rhythmic sound correlates to reaching being more efficient.

In addition to improving upper extremity functions, a study concluded that rhythmic auditory stimulation (RAS) also influenced lower extremity movement - in particular, standing balance and gait in hemiplegic stroke patients (Suh et al., 2014). The three-week research consisted of 16 hemiplegic participants completing gait training along with neurodevelopmental therapy. One group received RAS and the other did not. At the end of the intervention period, the results suggested that RAS improved stride length, cadence, standing balance, lower extremity weight bearing, and stride symmetry in the RAS group. The researchers found that the RAS activated spinal motor neurons, reduced muscle fatigue and reaction time of the automated movement, and improved latency and quality of the response (Suh et al., 2014). The results from Suh et al. are significant not only for Therapeutic Listening® Bilateral Quickshift as it involves bilateral coordination, but also for occupational therapy in general as sound can be used to improve fall prevention in clients with hemiplegia.

Sound and Fine Motor Skills. Furthermore, the task of producing sound can also prove to have a profound effect on fine motor skills in stroke patients (Schneider et al., 2010). In the three-week trial, a music-supported group produced tones, scales, and simple melodies on an electronic piano or electric drum set in addition to conventional physiotherapy (Schneider et al., 2010). Meanwhile, the control group only received conventional physiotherapy and functional motor training. The researchers used a series of fine motor assessments and found improvements in finger tapping, the Box and Block test, the Nine hole Pegboard, Action Research Arm test, and the Arm Paresis Score in the music-supported group. The results suggested the intervention group exhibited more improvements in fine motor skills, in comparison with the control group. Additionally, a participant noted that the music-producing intervention was “highly enjoyable” - which parallels occupational therapy’s commitment to incorporate meaningful activities into interventions (Schneider et al., 2010). Research has shown the relationship between sound and movement has been profound and sound based interventions have been used consistently over the past century. A key outcome of the use of sound to facilitate movement is an improved quality of movement as seen in improved force rhythm and timing of movement.

Current Study

Given the promise for using sound as an intervention for improving the quality of movement and bilateral coordination in particular, the current study aims to examine changes in the quality of movement following Therapeutic Listening® intervention. In particular, this study will continue the work of Ben-Haim et al., (2015) and Aroura et al., (2015) who examined the effectiveness of Therapeutic Listening® Bilateral Quickshift. The current study will reexamine the video data for changes in the quality of movement during the administration of the assessment of bilateral coordination.

In the Ben-Haim et al., (2015) and Aroura et al., (2015) studies, three assessments were used to measure bilateral coordination in typically developing children. The assessments used consisted of the Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition* (BOT-2), the Sensorimotor Performance Analysis (SPA), and the Quick Neurological Screen Test, *Third Edition* (QNST-3).

Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition* (BOT-2). The BOT-2 is designed to measure gross and fine motor skills in children. The bilateral coordination subtest of the BOT-2 was used in order to assess bilateral motor performance before and after Therapeutic Listening® Quickshift or white noise interventions. The bilateral coordination subtest included seven 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, tapping feet and fingers-opposite sides synchronized (Bruininks & Bruininks, 2005).

Quantitative measures were used to collect data from the use of the BOT-2. Subtest scores were recorded based on the number of correct and continuous movements maintained in each task. However, if the participant maintained the maximum number of continuous movements to complete each task, then full scores were received. For example, up to five correct jumping jacks are recorded. Qualitative measures were not included in this assessment. Therefore, data of the fluidity, symmetry, or exaggeration of movements was not recorded (Bruininks & Bruininks, 2005).

Sensorimotor Performance Analysis (SPA). The SPA is designed to measure sensory processing, postural responses and control, and gross and fine motor coordination and planning. The two components used in the previous study were the Belly Crawl and the Log Roll to assess motor planning and coordination in upper and lower extremities. Qualitative scores were given to measures, such as body righting and lateral trunk movement, which were assessed for each of the two SPA components. Scores of a 1, 3, or 5 were given for each measure, with 1 representing poor performance and 5 representing optimal performance (Richter & Montgomery, 1995). Although the SPA allowed for the collection of both quantitative and qualitative data, the exclusion of receiving a 2 or 4 score limits the ability to assess changes in movement in greater detail between a 1 to 3 or 3 to 5. The qualitative measures assessed in the SPA for the Belly Crawl and the Log Roll failed to capture the quality of movement in the participants of the previous study (Richter & Montgomery, 1995).

Quick Neurological Screen Test, *Third Edition* (QNST-3). The QNST-3 is designed to detect neurological soft signs with children as young as five years and individuals through geriatric ages. Three clinical observation tasks were administered to assess bilateral coordination. Two of the tasks from the QNST-3 included the rapid forearm movement and the backwards tandem walking. Qualitative measures, such as hand position and asymmetry, were observed in both of the tasks, with the number of continuous palms-up and palms down movements and steps taken walking heel to toe, backwards that were completed within 10 seconds given for each task providing quantitative measures (Mutti, Martin, Sterling, & Spalding, 2012).

The Infinity Walk Observational Assessment (IWOA). The IWOA was administered as the third clinical observation task. Qualitative measures, such as gait pattern and crossing of midline, were assessed while the participants walked in a figure eight pattern. The number of figure eight patterns completed within 20 seconds provided a quantitative measure (Ben-Haim et al., 2015).

Quantitative data was collected from the QNST-3 and IWOA. Though qualitative data was not formally gathered or scored, qualitative measures, such as fluidity and exaggerated or extraneous movements, were observed and reported while the participants completed the tasks. Although, guidelines were provided to assess qualitative measures in all three of the tasks, similar to the BOT-2 and SPA, they failed to capture specific measures observed in the quality of movements in the participants of the previous study (Ben-Haim et al., 2015).

The current study aims to capture the quality of movement in regards to trunk posture, arm and leg movements, symmetrical movements, fluidity and rhythmicity, effort, and precision. Understanding and capturing the quality of movement is an important aspect of occupational therapy. Therapeutic interventions are often aimed at changing movement patterns or increasing one's capacity to move and therapeutic strategies are created to help improve the quality of movement needed for function (Shumway & Woollacott, 2007). Therefore, exploring how movement is affected by Therapeutic Listening® is important to clinical practice.

Conclusion

The key findings in this literature review illustrate the systematic functions of the body, the origin of sound therapy, the state of current motor assessments, and the therapeutic connection between sound and movement. Previous studies have examined the effectiveness of Therapeutic Listening® on bilateral movement, but trends point toward improvements that quantitative scores fail to capture improvements seen in the quality of movement. Thus, this gap in the evidence for Therapeutic Listening® and bilateral coordination will guide the following research.

Purpose Statement

Currently there is limited research showing the effectiveness of Therapeutic Listening® in occupational therapy. Therapeutic Listening® is proposed to improve function in many areas including postural development and motor coordination. The Therapeutic Listening® Quickshift series in particular is proposed to improve bilateral motor coordination. A recent randomized controlled study examined the effectiveness of Therapeutic Listening® Bilateral Quickshift in improving bilateral coordination (Ben-Haim et al., 2015). However, the results did not show significant differences in standardized scores on tests of bilateral motor coordination between groups of typically developing children who listen to the Therapeutic Listening® versus white noise. The researchers concluded the measures' scores were not sensitive enough to detect change. Yet, the researcher noted that children who listened the Therapeutic Listening® Bilateral Quickshift had improved quality of movement not captured by standardized test scores. Sound based therapy is widely used by occupational therapists and could potentially positively impact large populations of children, such as those with SPD. Therefore, the purpose of this research study is to examine the effectiveness of Therapeutic Listening® on the quality of movement during bilateral coordination tasks. This study will build on the existing data collected by previous studies by coding videos for the analysis of the quality of movement in typically developing children with an objective, and qualitative measure of bilateral movement. Thus, our research question is:

1. For typically developing children, is the Therapeutic Listening® Bilateral Quickshift, when compared with white noise, more effective in improving bilateral coordination as measured by the quality of movement during bilateral tasks?

Theoretical Framework: Sensory Integration

As mentioned in the preceding overview, Jean Ayres, Ph.D, OTR, developed the sensory integration theory in the 1960's. This theory was developed to help with learning and developmental disorders. The SI theory guides both assessments and interventions for individuals with dysfunctions adversely impacting function, occupational performance, and participation (Schell, Gillen, & Scaffa, 2014).

Five Basic Propositions

There are five basic propositions that make up the SI theory. First, the theory is based on the potential for change in the developing brain (neuroplasticity) throughout the lifespan (Schell, Gillen, & Scaffa, 2014). Second, the interactions between the 'higher order' (cortical) and 'lower order' (subcortical) areas of the brain are fundamental for sufficient sensory integration (Schell, Gillen, & Scaffa, 2014). Third, sensory integration is based on the assumption that neurophysiological development of sensory integrative functions occurs in a natural order and follows a basic sequence (Schell, Gillen, & Scaffa, 2014). Fourth, sensory integration is based on adaptive responses, the ability to adjust actions to environmental demands, which promotes a higher level of integration due to feedback to the CNS (Schell, Gillen, & Scaffa, 2014). Finally, the presence of an inner drive to meet and master a challenge fosters the development of sensory integration (Schell, Gillen, & Scaffa, 2014).

The Four Levels of Sensory Integration

The four levels of sensory integration developed by A. Jean Ayres (2005) describe the development of typically developing children through the sensory integration process. In addition, the relationship between sensory systems during the developmental process of a typically developing child is explained. The first level of sensory integration is focused on touch, proprioception, and vestibular sensations (Ayres, 2005). According to Ayres, a primal source of comfort and security are tactile sensations (Ayres, 2005). An infant needs bodily contact with his/her caretaker to recognize his/her caregiver as a source of comfort and security (Ayres, 2005). A touch from a caregiver provides the child with tactile input that helps develop self-awareness (Ayres, 2005). Touch, proprioception, and vestibular sensations aid the child in developing gravitational security (Ayres, 2005). Gravitational security allows the child to trust that he/she has a firm connection to earth's surface (Ayres, 2005). If attachment to a caregiver and earth's surface is incomplete, the child may have a harder time making emotional attachments later in life (Ayres, 2005). Proprioception and vestibular sensations allow the child to control his/her eye movements (Ayres, 2005). Having control over eye movements and head position allows the child to focus on objects or his/her caregiver (Ayres, 2005). Being able to focus or perceive the caregiver aids with learning language, which will be further discussed at the third level of sensory integration (Ayres, 2005).

The second level deals with organizing a body map. The body map provides information about the parts of the body, the relationships among the body parts, and the movements the body parts can make (Ayres, 2005). Body maps allows for the child to coordinate left and right sides of the body (Ayres, 2005). If a child did not have successful tactile input from a caregiver and earth's gravity, developing a body map becomes more challenging (Ayres, 2005). As development of a body map is delayed, the ability to motor plan is affected (Ayres, 2005). Motor planning, which allows children to adapt to an unfamiliar task and have automatic responses, is dependent on a well-developed body map (Ayres, 2005).

At the third level, children learn to understand words by paying attention to the speaker, which requires the child to keep his/her head upright (Ayres, 2005). In order for a child to keep his/her head upright, a child needs vestibular system development to sense the orientation of his/her head in relation to earth's surface (Ayres, 2005). If the child had difficulties with the first level of sensory integration (touch, proprioception, and vestibular sensations), language development and the auditory system is negatively affected (Ayres, 2005). In order to learn to speak, the child needs sensation from the mouth to understand what shape the lips are making and how the tongue is moving (Ayres, 2005). Having a poorly developed self-awareness and body map makes feeling and dictating lip/tongue movement more difficult (Ayres, 2005).

The fourth level describes the process in which the parts of the brain specialize. A well-developed body map makes specializing the brain less strenuous (Ayres, 2005). If each level of sensory integration is well developed during the child's development, the parts of the brain begin to interpret specific types of sensory input with greater efficiency (Ayres, 2005). An example would be a child developing a dominant hand for writing (Ayres, 2005).

As described by the four levels of sensory integration, the sensory systems are interdependent. Without a well-developed brain centers for touch, proprioception, and vestibular sensations, an individual's visual, motor, and auditory systems are negatively impacted (Ayres, 2005). As illustrated previously, the auditory system development is dependent on the development of the vestibular and proprioceptive systems (Ayres, 2005). Through the interdependency between sensory systems, Therapeutic Listening® Quickshift aims to provide organized auditory sensations that stimulate a bilateral response from the vestibular system.

SI and Therapeutic Listening® Quickshift

SI theory will guide our perspective of the results from this study. If the results provide a positive impact of Therapeutic Listening® Quickshift on bilateral movement, Ayres' theory that sound and movement have a relationship will be reinforced. A key principle of sensory integration is that the selective use of sensation to elicit an adaptive response can improve behavioral and central nervous system organization. SI theory predicts that the enhanced auditory sensation provided by Therapeutic Listening® Bilateral Quick Shift will lead to an adaptive response specific to improved bilateral movement. Additionally, Therapeutic Listening® Quickshift will have the needed additional research that supports the use of Quickshift as a beneficial adjunct to SI intervention for individuals with SPD.

Methodology

Design

This study followed a randomized control pretest posttest experimental research design to test the effects of Therapeutic Listening® on bilateral movement. This study was a continuation of a previous study and focused on analyzing the children's performance based on the quality of movement (Ben-Haim et al., 2015). In the previous randomized controlled study, the participants' bilateral movement was assessed before listening to assigned recordings to determine a baseline. Children participating in the study were randomly assigned to a Therapeutic Listening® group or white noise group. After listening to assigned recordings, the participants' bilateral movement was assessed. In the previous study, pre and posttest of scores on several standardized measures. In the current study, quality of movement will be assessed using a quantitative scoring criteria. Separate scoring criteria were established for each test item. In addition, several common factors were scored for each item. The factors were trunk posture, arm and leg movements, symmetrical movements, bilateral coordination, fluidity and rhythmicity (smooth and continuous movements), effort, and precision. The independent variable of this study was the Therapeutic Listening® Bilateral Quickshift or white noise recordings. The dependent variable was the child's quality of movement.

Participants

For this study participants were previously recorded performing bilateral tasks. Therefore, no further participants were recruited, but rather the videos recorded from the original study were analyzed. The participants were 31 typically developing children aged seven to eleven years old and included 12 boys and 19 girls (see Table 1 for demographic information). Participants were recruited from Coleman Elementary School in San Rafael, California. Inclusion criteria for participation was English-speaking seven to eleven year olds. Exclusion criteria were that the children had no cognitive, mental, or physical disabilities, including sensory processing dysfunction, as determined by a questionnaire completed during recruitment.

Legal and Ethical Considerations

The study was approved by the Internal Review Board for the Protection of Human Subjects of Dominican University of California. Consent and permission was obtained from by parents and caregivers to allow researchers to videotape their child for future review in the previous study.

Measures and Instruments

Bilateral coordination was measured in the first phase of the study through a series of standardized and non-standardized assessments where participants' performance was videotaped. In the present phase of the study, bilateral coordination was assessed quantitatively through video analysis of the participants' quality of movement during tasks. A coding tool was created to capture the quality of movement in factors such as trunk posture and movement, arm and leg movements, symmetry, fluidity, precision, and effort (see Appendix A for the coding tool).

Bruininks-Oseretsky Test of Motor Proficiency, *Second Edition*. The bilateral coordination subtest of the BOT-2 was used which includes 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. This subtest has a possible score of 24 and the child had the opportunity to complete two trials. The BOT-2 has an internal consistency reliability of 0.76, 0.87, and 0.79 for children ages 8-10, with standard errors of measurement 2.25, 1.69, and 2.02. Test-retest reliability correlation coefficients for children ages 8-12 are 0.65 and 0.71. Inter-rater reliability coefficients for ages 4-21 are 0.98 and 0.98 (Bruininks & Bruininks, 2005).

Sensorimotor Performance Analysis. The two components of the SPA used in the previous study were the Belly Crawl and the Log Roll. These were scored from 1 to 5.Test-retest reliability ranged from .89 to .97 in a preliminary assessment of reliability, and interrater reliability was .76. The SPA currently has no validity studies, although its use in clinical settings has shown accuracy in assessing current status, or concurrent validity (Richter & Montgomery, 1995).

Quick Neurological Screening Test, *Third Edition*. Three additional clinical observation tasks were administered to children in the first study. The first two tasks were screens from the Quick Neurological Screening Test, *Third Edition* (QNST-3). The first of which was forearm rotation and the second backwards tandem walking. Quantitative measures were provided by the amount of movements completed in 10 seconds for each task. The third task was the Infinity Walk Observational Assessment (IWOA). A quantitative measure was provided by the amount of figure eight patterns completed in 20 seconds.

Video Analysis and Coding Tool. All assessments and observations were videotaped and will be reviewed to quantify the qualitative results. A coding tool will be created in collaboration with clinical experts to identify approximately eight to ten dimensions of quality of movement that should be measured when coding. The dimensions will include qualities of movement, such as symmetry and fluidity. The dimensions identified will be used consistently with coding all of the videotapes of the assessments and observations from the previous study. A global impressions scale of improvement will then be used to identify if changes in quality of movement were seen overall in the analysis of the videotapes.

Data Collection

Procedures. The videos were produced from an antecedent study by Ben-Haim et al. (2015) and Aroura et al. (2015). Their research team collected data through a pretest and posttest method. Participants were tested after school in a classroom or gym. In order to ensure a randomized study, each participant was randomly assigned to a condition - either Therapeutic Listening® or white noise. The participants were not informed of the effects of each condition, while the coders were not aware of the type of interventions that the children were listening to; thus facilitating a double blind study. The pretest consisted of the BOT-2 bilateral coordination subtest, two tasks from the SPA, three clinical observation tasks, and two Likert surveys. Immediately after the pretest, the interventions were administered in accordance to the child's assignment: Therapeutic Listening® or white noise. Thereafter, the posttests were administered. In total, the whole data collection process amounted to between 32-42 minutes, with the pretest taking 10-15 minutes, the intervention taking 15 minutes, and the posttest taking 7-12 minutes. During the pretest and posttest, the participants were video recorded for later analysis.

For the current study, the videos from the preceding study were further analyzed for quality of movement using a quantifiable coding tool. There were two teams of coders with two researchers on each team. Team #1 scored the BOT-2 bilateral coordination subtests while Team #2 scored the infinity walk, log rolling, crawling, and rapid forearm rotation using the created coding tool. In order to establish reliability and validity there was a 25% crossover amongst the pairs. One researcher was designated to control all the videos and was responsible for randomly assigning them for the coding teams. The coders were blind to whether the video was a pretest or posttest and pretest and posttest videos were not coded in the same week.

Data Management. To maintain confidentiality, the participants' videos were assigned a number instead of their names. The master sheet with the participants' names and corresponding numbers were kept in a locked file in the advisor's office. Only the faculty advisor and one researcher had access to the master list. The master sheet with the participants' identities, the raw data of field notes, and the assessment forms were stored separately from each other in a locked cabinet in the advisor's office. The computerized video data was kept on an external hard drive and several thumb drives, all of which were also be kept locked in a filing cabinet in the advisor's office. The tapes and data will be destroyed after a period of one year upon completion of the study.

Data Analysis. After watching each video, the researchers coded the quality of the bilateral movement using the created coding tool. The data was recorded by the researchers on paper forms or electronic for each video. A different Excel file for each task was created and the raw data was then transferred to the corresponding Excel files. From there, the Excel files were converted into SPSS files. Descriptive statistics on each group and measure were performed as part of the data analysis for this study. Through the SPSS program, a repeated measures ANOVA was conducted to compare the mean pretest and posttest scores for the key global factor scores and each of the item total scores that trended towards significance in the previous study. Significance level was set as $p=.\leq.05$.

Results

Preliminary analysis was conducted to examine the data for outliers. Overall, thirty out of thirty-one participant's data were analyzed. One participant was eliminated due to excessive missing video data. Sixteen participants received the Therapeutic Listening® intervention while fourteen participants were in the control group and listened to white noise. All thirty participants completed the pretest and posttest assessments. A mixed model repeated measure ANOVA was conducted to compare the differences in group scores between the pretest and posttest on global items and specific tasks between the intervention group and the white noise control group. Table one displays all of the demographic information for the 31 participants.

Table 1

Demographic Information

	Therapeutic Listening® (Experimental)	White Noise (Control)	Total
N	16	14	31
Male	9	3	12
Female	8	11	19
Age M	106	100	
Ethnicity			
1 African American	0	0	0
3 Asian or Pacific Islander	2	3	5
4 Hispanic	14	10	24
5 White	1	1	2
6 Other or Unknown	0	0	0

Notes: (SD) = *standard deviation*

Global Scores

Overall the difference in the pretest and posttest were analyzed in the areas of rhythmicity, smooth and continuous movement, effort and motor planning, and symmetry and synchrony of the upper and lower extremity. The repeated measure ANOVA showed a moderately significant difference in smooth and continuous movement, while the other global scores trended towards significance (see Table 2). The effect of the intervention was small, but had a slight advantage over the control group for smoothness and rhythmicity (see Figure 1). Table two shows the comparison of means on global factors between experimental and control pretest posttest groups. As seen in table three, the ANOVA descriptive statistics on the global factor scores.

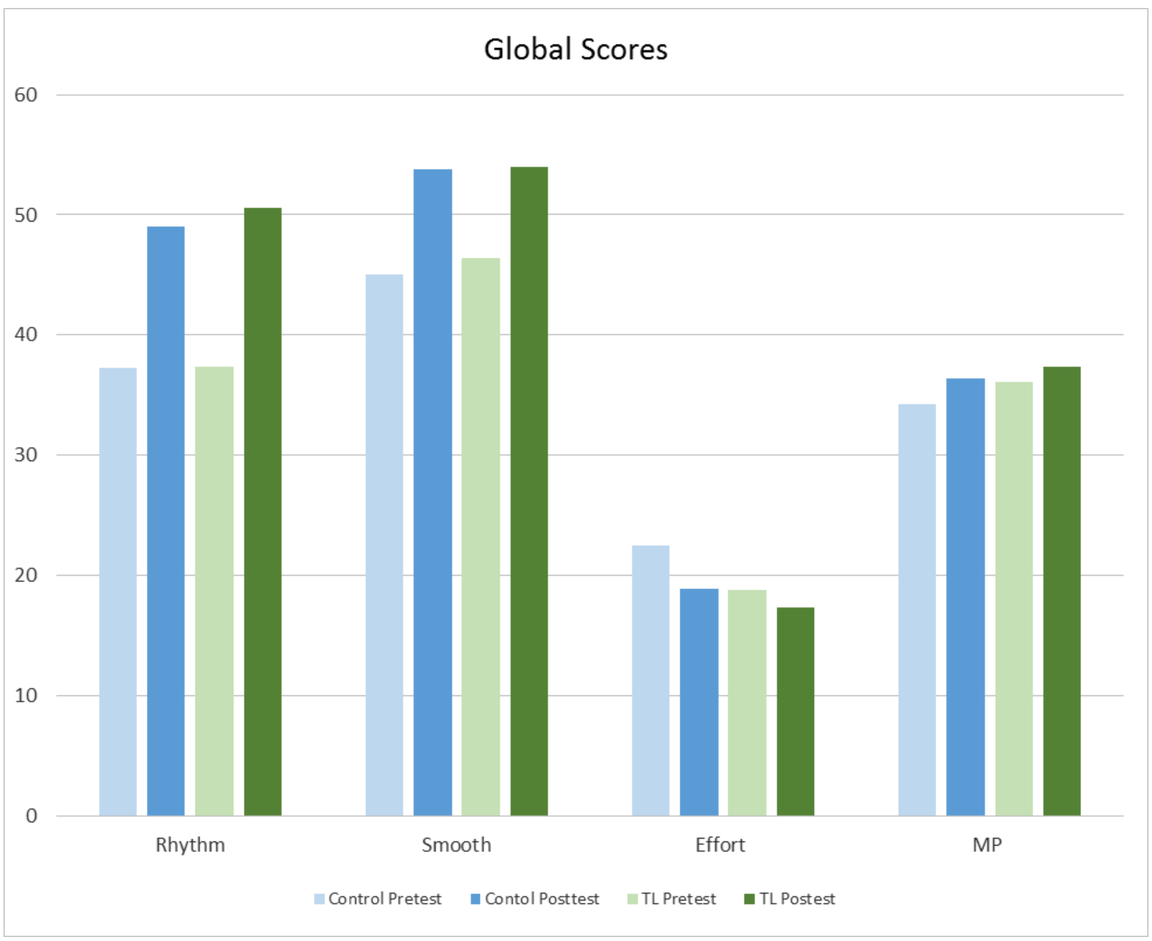

Table 2

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

	CONTROL (WN)		EXPERIMENTAL(QS)	
	Pretest	Posttest	Pretest	Posttest
FACTORS	M (SD)	M (SD)	M (SD)	M (SD)
MOTOR PLANNING	34. 15(2.54)	36.15 (2.57)	36.07 (3.07)	37.64 (1.69)
SMOOTH & CONTINUOUS	45.08 (3.94)	53.76 (4.10)	46.38 (4.77)	54.00 (3.97)
RHYTHM	37.25 (3.39)	49.00 (4.97)	37.37(4.46)	50.62 (3.70)
EFFORT	21.73 (5.25)	17.82 (2.27)	18.78(5.53)	15.79 (3.62)
MOTOR PLANNING 2	33.84 (2.91)	36.15 (2.57)	36.07 (3.07)	37.35 (1.78)

Notes: M= Mean (SD) = Standard Deviation

Table 3

ANOVA of global scores

FACTORS	F	DF	P-VALUE	EFFECT
SMOOTH & CONTINUOUS				
WITHIN	178.67	1,23	>.001	
BETWEEN	3.6	1,23	.07	.
GROUP X FACTOR	.032	1,23	.85	
RHYTHM				
WITHIN	285.33	1, 26	>.001*	.923
BETWEEN	1.20	1, 26	.54	.015
GROUP X FACTOR	1.20	1, 26	.32	.038

Item Scores

From the global scores further analysis was conducted on the specific items after eliminating those with a strong ceiling effect and isolating the items that approached significance in the previous quantitative study. A mixed model repeated measure ANOVA was run to determine the differences between the pretest and posttest in the following items: scissor jumps opposite sides, backward tandem walk, tapping feet and fingers opposite side, and infinity walk (see Table 4). Overall, the Quickshift series showed to have a moderate effect on the qualitative movement during bilateral tasks by improving smoothness and rhythmicity for specific tasks.

Table 4

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

	CONTROL (WN)		EXPERIMENTAL (QS)	
	Pretest	Posttest	Pretest	Posttest
ITEM	M (SD)	M (SD)	M (SD)	M (SD)
BACKWARD TANDEM WALK-SMOOTH	3.93(.27)	4.5(.65)	3.88(.34)	4.62 (.5)
BACKWARD TANDEM WALK-RHYTHM	3.92(.28)	4.62 (.5)	3.87(.34)	4.81(.40)
INFINITY WALK-RHYTHM	4.79 (0.426)	4.57 (0.514)	4.69 (0.602)	4.94 (0.250)
INFINITY WALK-SMOOTH	3.93 (0.27)	4.5 (0.65)	3.94(0.250)	4.94 (0.250)
BOT -SCISSOR JUMPS OPPOSITE SIDE-RHTHYM	2.64 (1.40)	4.64 (.75)	2.56 (1.46)	4.88 (.5)
BOT-SCISSOR JUMPS OPPOSITE SIDE-SMOOTH	2.14 (1.29)	3.50 (1.51)	2.5 (1.41)	3.63(1.86)
BOT-TAPPING FEET/ FINGERS OPPOSITE-RHYTHM	1.57 (0.85)	3.36 (1.69)	2.31(1.40)	3.44 (1.79)
BOT-TAPPING FEET/ FINGERS OPPOSITE -SMOOTH	1.79 (1.25)	3.79 (1.42)	2.37 (1.31)	3.5 (1.826)

Notes: M= Mean (SD) = Standard Deviation

Table 5

Group by Factor ANOVA for specific item scores

ITEM	F	df	P-value	Effect
BACKWARD TANDEM WALK-SMOOTH	.54	1,28	.47	.019
BACKWARD TANDEM WALK-RHYTHM	1.20	1,27	.283	.043
INFINITY WALK-SMOOTH	4.073	1,28	.05	.127
INFINITY WALK-RHYTHM	3.374	1,28	.077*	.108
BOT-SCISSOR JUMPS OPPOSITE SIDE-RHTHYM	.271	1,28	.61	.010
BOT-SCISSOR JUMPS OPPOSITE SIDE-SMOOTH	.198	1,28	.66	.007
BOT-TAPPING FEET/ FINGERS OPPOSITE-SMOOTH	1.958	1,28	.173	.065
BOT-TAPPING FEET/ FINGERS OPPOSITE - RHYTHM	1.302	28	.264	.044

*Only TL group differed between pre and post test

Discussion

The purpose of this study was to continue to determine the effect of Therapeutic Listening® on bilateral coordination. Currently, there is limited research and evidence to support the use of Therapeutic Listening® as an intervention, yet many occupational therapists continue to administer the sound-based therapy to children. Overall, the findings from this study suggest binaural beats such at the Therapeutic Listening® Quickshift series have an effect on motor coordination in particular the smoothness of movements.

The focus of this study was to examine the quality of movement through a series of bilateral tasks. The quality of movement was captured through a more sensitive coding tool and after analysis when compared to the white noise group, the intervention group showed a trend for improvement in motor coordination. Overall, there was a significant practice effect. Both the intervention and control groups' score improved between pre-test and posttest. However, there was a slight advantage on the quality of movement after a Therapeutic Listening® intervention session. The qualitative items of smooth and continuous, and rhythm showed an advantage for the Therapeutic Listening® Quickshift while other items such as motor planning and effort had little or no change.

The results of this continuation study mirrored those of the previous quantitative study, some changes in movement moved showed greater changes. In the previous study several test items trended towards an improvement in standardized test scores. Those items were scissor jumps opposite sides, tapping feet and fingers opposite side, backward tandem walk, and the infinity walk. When comparing the study from 2015 to the current study, similar results were found and therefore, supports the current hypothesis that an effect of the Therapeutic Listening® Quickshift series on bilateral coordination exists.

Limitations and Future Recommendations

Limitations of this study included low statistical power, a high ceiling effect, a practice effect, and generalizability from a typical population. The small sample size of videos obtained from the previous study presented a limitation, as only 30 videos of children from one elementary school were analyzed, this led to the results having a lower statistical power. Another limitation includes the generalizability of this study since the videos obtained were only of typically developing children. In contrast, Therapeutic Listening® is generally used with children with motor delays or deficits. However, Therapeutic Listening® shows promise as an intervention due to results indicating a slight advantage in the intervention group although there was less room for improvement with typically developing children. Similarly, there was a high ceiling effect since the participants were typically developing children. Most scores on the BOT-2 for example reached ceiling on the pre-test. Coincidently the children randomly assigned to the intervention group were on average closer to ceiling than the control group in the pretest which left less room for improvement in the posttest. Anecdotally, a few children in the control group who scored low on the pretest did make qualitative improvements in the posttest. Additionally, a practice effect could be present as the children completed the pretest and posttest tasks within 30 minutes of each other. Lastly, quantifying the movements through video recordings instead of assessing in person, limits the integrity of the observations as the video quality was not optimal. Video analysis could also lead to the possibility of a data entry error due to a large data base of coding information.

Given the limitations of this study, future research should consider using a larger, more diverse sample size. A larger sample including children with motor or sensory delays/deficits may detect a more significant difference due to increasing statistical power, and decreasing the chance of ceiling. Another recommendation for future research would be to increase the frequency and total time the children spent listening to the Quickshift series or the white noise as a longer duration may change the qualitative performance on the assessments. A significant difference may be determined in scoring if the filming and administration of tasks remains consistent throughout the time period of the study.

Conclusion

Sound based therapy is widely used by occupational therapists and could potentially positively impact large populations of children, such as those with SPD. Although, research has determined that sound and movement are related through the auditory and vestibular systems, little research shows the effectiveness of Therapeutic Listening® on bilateral coordination. The purpose of this study was to provide evidence-based research to determine the qualitative effect of Therapeutic Listening® on bilateral coordination in typically developing children by creating a more sensitive, objective, and quantitative measure. The Quickshift series showed promise as a therapeutic intervention to improve bilateral coordination and this study, together with the standardized test scores from the previous study have a strong trending effect of Therapeutic Listening® on bilateral coordination.

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Appendix A
Coding Tool

Scales				
Movement: 1= almost never 2= seldom 3= sometimes 4= often 5= almost always	**Effort:** 1= not effortful 3= somewhat effortful 5= very effortful	**Smooth and Cont./Rhythm** 5= Fluid and Rhythmic 3= somewhat F & R 1= Discontinuous and Arhythmical	**Alignment** **5=** align with spine 0-10 4 10-20 3 neck flexion 30 (+/-10 2 40 -60 1= neck flexion > 60	**Angle Degrees** 1 = 90-76 2 = 75-61 3 = 60 – 31 4 = 30 - 16 5 = 15 - 0 When in doubt give better score.

TASK TEMPLATE						
	1	*2*	*3*	*4*	*5*	*NS*
	5	4	3	2	1	NS
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
• Alignment: Rotation (Top-bottom alignment)	5	4	3	2	1	NS
• Stability: Movement side to side (sway)	5	4	3	2	1	NS
• Stability: Movement front to back (sway)	5	4	3	2	1	NS
Trunk Movement						
• Symmetry of movement: right and left body sides	5	4	3	2	1	NS
• Separation: Flexion and extension						
• Separation: Rotation						
• Righting reactions						
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Arm Swing						
• Smooth and Continuous	5	4	3	2	1	NS

• Reciprocal and Contralateral	5	4	3	2	1	NS
• Symmetrical	5	4	3	2	1	NS
Hands/ Feet						
• Position Appropriate	5	4	3	2	1	NS
• Action or Use	5	4	3	2	1	NS
• Overflow	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Efficient	5	4	3	2	1	NS
Precision						
Task Specific						

Section 1

BOT- 2 Bilateral Coordination Subtest

Touching Nose with Index Finger						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
• Alignment: Rotation (Top-bottom) alignment (degree)	5	4	3	2	1	NS
• Stability: Movement side to side (sway)	5	4	3	2	1	NS
• Stability: Movement front to back (sway)	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Shoulder angle: Starting	R:		L:			
• Shoulder angle: Best point	R:		L:			
• Shoulder angle: Worst point	R:		L:			
• External Rotation	R	Y/N	L	Y/N		
• Internal rotation	R	Y/N	L	Y/N		
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Precision : Number of Finger Touches	/4					

Jumping Jack						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS

• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
• Alignment: Rotation (Top-bottom) alignment (degree)	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Efficient (learns pattern quickly)	5	4	3	2	1	NS
Precision						
• Arms	/5					
• Legs	/5					

Scissor Jumps Same Side						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Trunk Movement						
• Separation: Rotation	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Efficient (learns pattern quickly)	5	4	3	2	1	NS
Precision						
• Arms	/5					
• Legs	/5					

Scissor Jumps Opposite Sides						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Trunk Movement						
• Separation: Rotation	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS

• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Efficient (learns pattern quickly)	5	4	3	2	1	NS
Precision						
• Arms	/5					
• Legs	/5					

Tapping Feet and Fingers Same Side						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Hands/ Feet						
• Overflow/Extra taps	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Fluidity and Rhythmicity (Smooth and Continuous Movements)	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Precision						
• Correct number of finger/foot taps	/5					

Tapping Feet and Fingers Opposite Side						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Hands/ Feet						
• Overflow/Extra taps	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS

Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Precision						
• Correct number of finger/foot taps	/5					

Section 2

BOT- 2 Bilateral Coordination Subtest

Pivoting Thumbs and Index Fingers (Spider)						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Hands						
• Symmetrical	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
• Hand Position Appropriate	5	4	3	2	1	NS
• Overflow	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning:: Efficient	5	4	3	2	1	NS
Precision						
• correct number of rotations	/5					NS
Movement Up or Down	Yes		No			NS

Quick Neurological Screening Test - 3

Rapid Forearm Rotation						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Hands/ Feet						
• Position Appropriate	5	4	3	2	1	NS
• Overflow	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS

Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Precision: Number correct in 10 seconds	/10					
Uses floppy rotation or unusual finger movements*	Yes		No			NS
Employs unusually fast or slow rate (note which)*	Yes		No			NS
Displays double hand bounce, rigid, or tense finger position*	Yes		No			NS
Makes large circular motion (1 foot diameter)*	Yes		No			NS
Manifests asymmetry*	Yes		No			NS

Backward Tandem Walk						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
• Alignment: Rotation (Top-bottom) alignment (degree)	5	4	3	2	1	NS
• Stability: Movement side to side (sway)	1	2	3	4	5	NS
• Stability: Movement front to back (sway)	1	2	3	4	5	NS
Lowers Center of Gravity	1	2	3	4	5	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
Arm Swing						
• Symmetrical	5	4	3	2	1	NS
• Smooth and Continuous (movement)	5	4	3	2	1	NS
• Reciprocal and Contralateral	5	4	3	2	1	NS
• Position Appropriate	5	4	3	2	1	NS
• Overflow in hands	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Efficient	5	4	3	2	1	NS
Precision Correct/Total Steps	=Correct			=Total		
Task Specific						
Noticeable difficulty walking backwards*	Yes		No			NS
Irregular hand position*	Yes		No			NS
Crosses midline or veers right or left from midline*	Yes		No			NS
Cannot maintain accurate toe to heel walk*	Yes		No			NS
Exhibits pigeon- toed stance and bent knees*	Yes		No			NS
Demonstrates poor balance*	Yes		No			NS
Involuntary or spastic movements not related to balance	Yes		No			NS

Infinity Walk						

Starting Position Standard / Reverse						
Trunk posture						
• Alignment: Head, neck and spine	5	4	3	2	1	NS
• Alignment: right to left side (Symmetry)	5	4	3	2	1	NS
• Alignment: Forward/backward flexion and extension	5	4	3	2	1	NS
• Alignment: Rotation (Top-bottom) alignment (degree)	5	4	3	2	1	NS
• Stability: Movement side to side (sway)	1	2	3	4	5	NS
• Stability: Movement front to back (sway)	1	2	3	4	5	NS
Trunk Movement						
• Symmetry of movement between right and left body sides	5	4	3	2	1	NS
• Separation: Flexion and extension	1	2	3	4	5	NS
• Separation: **Trunk** Rotation when change in directions	5	4	3	2	1	NS
• Separation: **Head-Neck** Rotation when change in directions	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
• Arm position appropriate	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
Arm Swing						
• Smooth and Continuous	5	4	3	2	1	NS
• Reciprocal and Contralateral	5	4	3	2	1	NS
• Symmetrical (if no describe)						
Hands/ Feet						
• Position Appropriate	5	4	3	2	1	NS
• Overflow	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Strained Voice	1	2	3	4	5	NS
Motor Planning: Efficient	5	4	3	2	1	NS
Precision						
● number of times look down						
● number of passes across X						
● number of times touching cone						

<u>Belly Crawling:</u>						
Trunk Movement						
• Symmetry of movement between right and left body sides	5	4	3	2	1	NS
• Separation: Flexion and extension	5	4	3	2	1	NS
• Separation: Lateral Flexion	5	4	3	2	1	NS
• Righting reactions	5	4	3	2	1	NS

Arm and Leg movements						
• Symmetry between right and left body sides	5	4	3	2	1	NS
• Synchronous between arms and legs	5	4	3	2	1	NS
• Synchronous on right and left sides	5	4	3	2	1	NS
Hands						
• Position Appropriate (open palm/flat-cupped hands)	5	4	3	2	1	NS
• Action or Use Correct (pull with hands)	5	4	3	2	1	NS
Other:						
Feet						
• Position Appropriate (Toes flexed)	5	4	3	2	1	NS
• Action or Use Correct (push with toes)	5	4	3	2	1	NS
Other	1	2	3	4	5	NS
Rhythmical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Stays on line	5	4	3	2	1	NS

Log Rolling:						
Rolls in both directions	1	2	3	4	5	NS
Performance same in both directions	5	4	3	2	1	NS
Trunk Movement						
• Symmetry of movement between right and left body sides	5	4	3	2	1	NS
• Separation: Flexion and extension	5	4	3	2	1	NS
• Separation: Rotation	5	4	3	2	1	NS
• Righting reactions	5	4	3	2	1	NS
Arm and Leg movements						
• Symmetrical	5	4	3	2	1	NS
Smooth and Continuous Movements	5	4	3	2	1	NS
Effort	1	2	3	4	5	NS
Motor Planning: Stays on mat- rolls in a straight line	5	4	3	2	1	NS

Table 1

Demographic Information

	Therapeutic Listening® (Experimental)	White Noise (Control)	Total
N	16	14	31
Male	9	3	12
Female	8	11	19
Age M	106	100	
Ethnicity			
1 African American	0	0	0
3 Asian or Pacific Islander	2	3	5
4 Hispanic	14	10	24
5 White	1	1	2
6 Other or Unknown	0	0	0

Notes: (SD)= *standard deviation*

Table 2

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

	CONTROL (WN)		EXPERIMENTAL(QS)	
	Pretest	Posttest	Pretest	Posttest
FACTORS	M (SD)	M (SD)	M (SD)	M (SD)
MOTOR PLANNING	34. 15(2.54)	36.15 (2.57)	36.07 (3.07)	37.64 (1.69)
SMOOTH & CONTINUOUS	45.08 (3.94)	53.76 (4.10)	46.38 (4.77)	54.00 (3.97)
RHYTHM	37.25 (3.39)	49.00 (4.97)	37.37(4.46)	50.62 (3.70)
EFFORT	21.73 (5.25)	17.82 (2.27)	18.78(5.53)	15.79 (3.62)
MOTOR PLANNING 2	33.84 (2.91)	36.15 (2.57)	36.07 (3.07)	37.35 (1.78)

Notes: M= Mean (SD) = Standard Deviation

Table 3

ANOVA of global scores

FACTORS	F	DF	P-VALUE	EFFECT
SMOOTH & CONTINUOUS				
WITHIN	178.67	1,23	>.001	
BETWEEN	3.6	1,23	.07	.
GROUP X FACTOR	.032	1,23	.85	
RHYTHM				
WITHIN	285.33	1, 26	>.001*	.923
BETWEEN	1.20	1, 26	.54	.015
GROUP X FACTOR	1.20	1, 26	.32	.038

Table 4

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

	CONTROL (WN)		EXPERIMENTAL (QS)	
	Pretest	Posttest	Pretest	Posttest
ITEM	M (SD)	M (SD)	M (SD)	M (SD)
BACKWARD TANDEM WALK-SMOOTH	3.93(.27)	4.5(.65)	3.88(.34)	4.62 (.5)
BACKWARD TANDEM WALK-RHYTHM	3.92(.28)	4.62 (.5)	3.87(.34)	4.81(.40)
INFINITY WALK-RHYTHM	4.79 (0.426)	4.57 (0.514)	4.69 (0.602)	4.94 (0.250)
INFINITY WALK-SMOOTH	3.93 (0.27)	4.5 (0.65)	3.94(0.250)	4.94 (0.250)
BOT -SCISSOR JUMPS OPPOSITE SIDE-RHTHYM	2.64 (1.40)	4.64 (.75)	2.56 (1.46)	4.88 (.5)
BOT-SCISSOR JUMPS OPPOSITE SIDE-SMOOTH	2.14 (1.29)	3.50 (1.51)	2.5 (1.41)	3.63(1.86)
BOT-TAPPING FEET/ FINGERS OPPOSITE-RHYTHM	1.57 (0.85)	3.36 (1.69)	2.31(1.40)	3.44 (1.79)
BOT-TAPPING FEET/ FINGERS OPPOSITE - SMOOTH	1.79 (1.25)	3.79 (1.42)	2.37 (1.31)	3.5 (1.826)

Notes: M= Mean (SD) = Standard Deviation

Table 5

Group by Factor ANOVA for specific item scores

ITEM	F	df	P-value	Effect
BACKWARD TANDEM WALK-SMOOTH	.54	1,28	.47	.019
BACKWARD TANDEM WALK-RHYTHM	1.20	1,27	.283	.043
INFINITY WALK-SMOOTH	4.073	1,28	.05	.127
INFINITY WALK-RHYTHM	3.374	1,28	.077*	.108
BOT-SCISSOR JUMPS OPPOSITE SIDE-RHTHYM	.271	1,28	.61	.010
BOT-SCISSOR JUMPS OPPOSITE SIDE-SMOOTH	.198	1,28	.66	.007
BOT-TAPPING FEET/ FINGERS OPPOSITE-SMOOTH	1.958	1,28	.173	.065
BOT-TAPPING FEET/ FINGERS OPPOSITE - RHYTHM	1.302	28	.264	.044

*Only TL group differed between pre and post tests

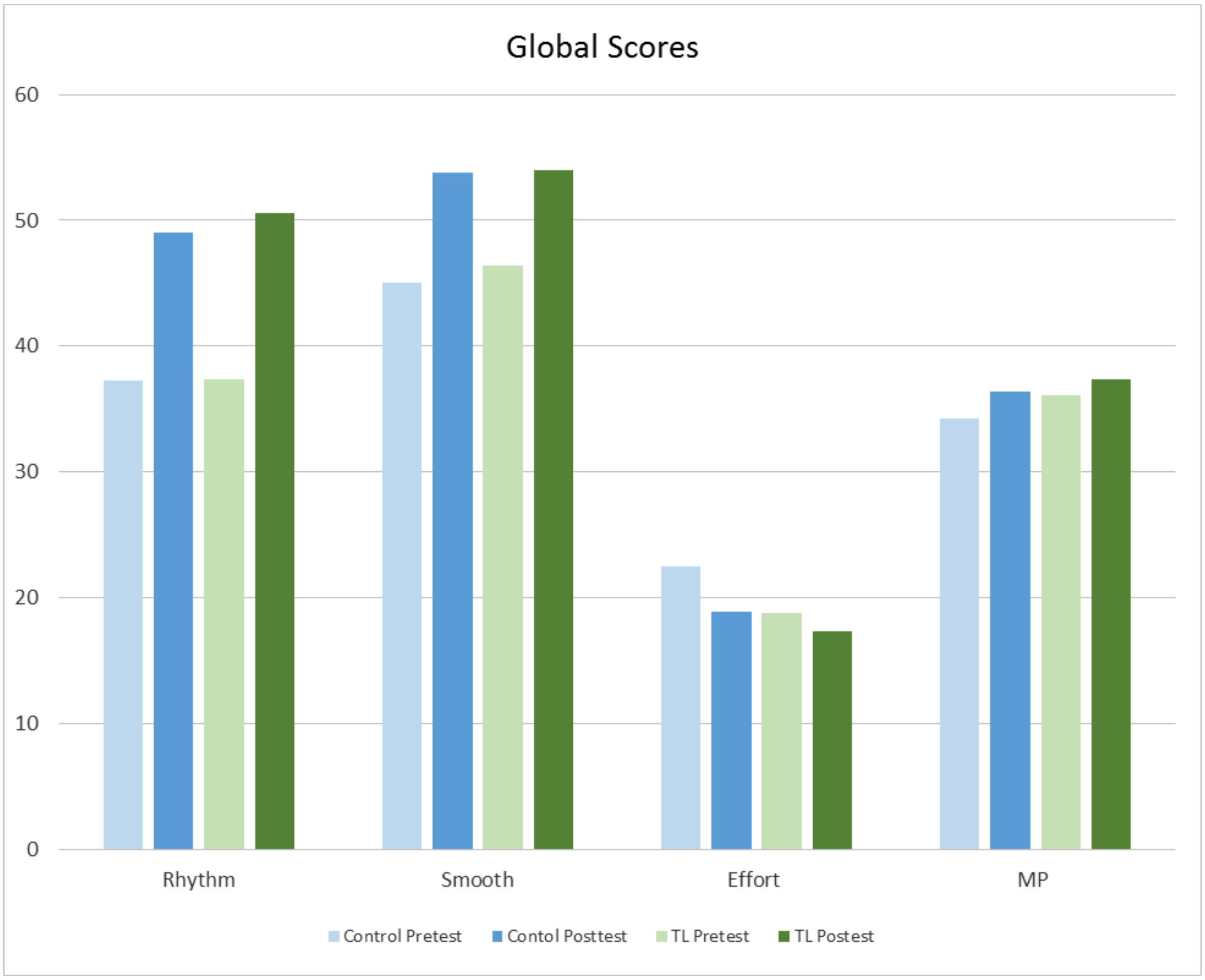

Figure 1: Comparison of mean for the global scores of rhythm, smooth movement, effort, and motor planning