THE EFFECT OF THE ELECTRONIC AUDITORY STIMULATION EFFECT (EASE) PROGRAM ON 8-12 YEAR OLD CHILDREN WHO EXHIBIT SENSORY PROCESSING DEFICITS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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To the Vice President and Dean of Brenau University,
I am submitting herewith a thesis written by Jessica Lambert, Shala Brooks, and Catharine Carroll entitled "The effect of the Electronic Auditory Stimulation effect (EASe) program on 8-12 year old children who exhibit sensory processing deficits." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Occupational Therapy.

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ABSTRACT

Objective: Researchers investigated the effect of Electronic Auditory Stimulation Effect (EASe) games and music CD's on changes produced in auditory, visual, and vestibular function in 8-12 year old children who are adversely affected by deficits in their sensory processing.

Method: Participants from two occupational therapy clinic locations followed the 28 day study protocol that involved playing an EASe game for 30 minutes twice a day for 14 days, then switched to another EASe game for the remaining 14 days of the trial. Researchers analyzed six participant game score datasets by applying a single subject and small group design using the Semiparametric Ratio Estimator (SPRE) model.

Results: The EASe Fun House game results in more sensory modulation than the EASe Off Road game as determined by lower mean and *p*-value scores plotted over individual scores. Data from participants using the Off Road game were inconsistent across participants, thus resulting in fragmented mean data.

Conclusion: Further studies on the EASe games' effect on children's sensory integrative abilities are justified based on a strong correlation between individual participant data and the mean data. Analysis using the SPRE allows for occupational therapists to make generalizations for similar populations when using EASe products as a therapeutic tool.

Keywords: Sensory Processing, Sensory Deficits, Sensory Integration Intervention, Auditory

Processing, Visual Processing, Vestibular Processing, Electronic Auditory Stimulation effect (EASe), Virtual Reality, Occupational Therapy

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CHAPTER 1

INTRODUCTION

Sensory processing deficits are defined as under-responsiveness, over-responsiveness, or a combination of under-/over-responsiveness to the reception, modulation, integration and organization of sensory stimuli or sensory input (Law, Missiuna, Pollock, & Stewart, 2005). These deficits are estimated to affect five to ten percent of children within the general population (Ahn, Miller, Milberger, & McIntosh, 2004). Such deficits affect a child's ability to perform daily occupations. Recent neurological studies purport that the brains of children with sensory deficits process sensory information differently than typically developing children, and that there may be different thresholds for coping with sensory input (Galvin, Froude & Imms, 2009). When children's brains are unable to use the information received from their senses efficiently, they possess an inaccurate model of the environment and thus are unable to adapt and respond appropriately (Williams & Schellenberger, 1996). This inability to adapt appropriately often results in maladaptive behaviors from the child. Subsequently, the child is often referred to occupational therapy for the assessment and treatment of problems associated with sensory processing (McIntosh, Miller, Shyu & Hagerman, 1999).

Children with sensory processing deficits often exhibit more "challenging behaviors and poorer social skills than typically developing children" (Cosbey, Johnston & Dunn, 2008, p. 470). Their ability to learn is affected when over-sensitivities and under-sensitivities cause distractions or decreased levels of alertness (Eide, 2003). Reynolds & Lane (2008) further noted that children with sensory processing disorders frequently have co-morbid diagnoses, such as

Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), Fragile X Syndrome, and learning disabilities. Often, children with sensory processing deficits are diagnosed with a combination of such disorders, compounding the effects of the children's sensory deficits (Koomar & Bundy, 2002).

Sensory information processed by the nervous system is unique to each human being, and is guided by the way an individual's brain interprets input from the seven sensory systems--visual, auditory, olfactory, tactile, gustatory, vestibular, and proprioceptive (Miller & Lane, 2000). Modern technology in brain imaging has allowed for an increased understanding of brain processes as they relate to sensory information. Sensory receptors receive sensory input from external sources (e.g. hearing a high pitch, touching a textured object with a finger), then transmit sensory information along pathways throughout the body to specific locations in the brain, forming pathway maps called neural networks. Sensory pathway maps, specifically auditory, visual, and vestibular pathway maps affect an individual's moods, temperament, and ways of organizing their life (Dunn, 2001). The integration of sensory information from multiple systems is essential for new learning, modulation of input, and adaptation within one's environment. As the brain develops, these sensory maps are naturally modified to adapt to each individual's experiences and the activities in which the person chooses to engage (Dunn, 2001).

Sensory processing

Sensory processing is an encompassing term that refers to the way in which the central nervous system (CNS) and the peripheral nervous system (PNS) manage incoming sensory information. Specifically, "the reception, modulation, integration, and organization of sensory stimuli, including the behavioral responses to sensory input" (Miller & Lane, 2000, p. 2) are all part of sensory processing. Typical childhood occupations, such as play and socialization, are negatively impacted when children have considerable difficulties processing and integrating sensory information (Ayres, 1972). Occupational therapists use a variety of assessments to evaluate a child's sensory deficits in the areas of visual, vestibular, and auditory skills (Spitzer, Roley, Clark & Parham, 1996). Examples of assessments that measure sensory processing function include the Sensory Processing Measure (SPM)-Home Form (Parham & Ecker, 2009), the Comprehensive Trail Making Test (CTMT; Reynolds, 2002), Sensory Integration and Praxis Test-Vestibular Function Subtest (SIPT; Ayres, 1989), and clinical observations. When the therapist conducts these sensory assessments in a variety of environments familiar to a child, such as home, school and clinic, a more accurate representation of the child's sensitivities may be achieved, as some sensitivities may not be as apparent in one setting versus another (Brown & Dunn, 2010).

A variety of theories guide the clinical reasoning of occupational therapists regarding interventions used with their clients. These may include: theories about occupation and the use of time, developmental theories and theories related to neurointegration and environment (Parham & Mailloux, 2005). One such theory, known as Sensory Integration (SI), is a framework based on Dr. A. Jean Ayres' (1972) model of sensory integration. After years of working with and observing children, Ayres postulated that some emotional and behavioral dysfunctions in children could be the result of the brain's inability to form neural networks that meet the needs of sensory processing and integration (Parham & Mailloux, 2005). SI uses the occupation of play as a motivating factor to engage children in a variety of rich sensory experiences. The therapist sets up play activities in the therapy room or in the home or school environment and collaborates with the child to choose activities that provide him or her with "just right" sensory challenges—a term coined by Ayres referring to the therapist's choice of treatment activities for a child that are neither too easy nor too difficult (Parham & Mailloux, 2005).

Pediatric occupational therapists often utilize the sensory integration frame of reference to guide their intervention to best address the needs of their clients with sensory processing deficits (Case-Smith & Arbesman, 2008). Sensory integration interventions address children's sensory difficulties by using the occupation of play as a vehicle to gradually increase exposure to sensory modalities (Dunn, 2001). The sensory integration approach is unique as it can be considered both deficit-based and occupation-based. Occupational therapists, clients, and families have reported positive changes from the use of sensory integrative based approaches (Polatajko & Cantin, 2010).

Guided by these theories, and based on the assessment of the client's strengths and deficits, the occupational therapist will design an individualized intervention program that addresses the client's needs. Biel & Peske (2005) emphasize the benefits of using a combination of therapies including home-based treatments. Occupational therapists utilize a variety of interventions to supplement clinic-based treatment in order to address sensory processing deficits in children. For example, Auditory Integration Training (AIT; AIT Institute for Berard Auditory Integration Training, 2011), Therapeutic Listening (Frick & Hacker, 2001), and various virtual reality interventions all gradually increase children's exposure to unfamiliar sensory input to increase their ability to adapt and react appropriately to new environments (Biel & Peske, 2005). An intervention plan for children with sensory-related difficulties might include virtual learning activities that have been shown to improve visual and perceptual skills (Reid, Wan & Herbert, 2009). Virtual reality interventions create an illusion of a three-dimensional interactive world within which the participant is fully immersed and which allows the participant to independently determine motion with appropriate environmental responses within the game (Strickland, Marcus, Mesibov & Hogan, 1996). The use of virtual reality "represents a safe, controlled and convenient environment" for the participant to respond to auditory, visual and vestibular input (Reid, Wan & Herbert, 2009, p. 44).

The Electronic Auditory Stimulation effect (EASe) system of interactive games is an example of virtual reality sensory integrative intervention that addresses visual, vestibular and auditory sensitivities in children with sensory deficits. The EASe program was developed by William P. Mueller in 1995 to promote auditory processing in children who are on the autism spectrum and for others who were experiencing difficulty with sensory processing. This program was developed to stimulate, challenge, and promote sensory processing and organization. Music provided in the EASe games and music CDs was encoded according to the principles of Auditory Integration Training developed by Guy Berard (Mueller, 2010).

In the mid 1900's, Alfred Tomatis researched the use of modified music on adults and children with attention deficit disorder and learning disabilities. He postulated that exposure to modified music would facilitate organization throughout the nervous system, thus helping his clients integrate daily sensory input. Tomatis created a program that involves the user listening to specialized music through a device he invented known as the Electronic Ear (Hall & Case-Smith, 2007).

Dr. Guy Berard worked closely with Alfred Tomatis and expanded upon Tomatis's work. He pioneered the first auditory integration training (AIT) treatments at his ear, nose and throat practice in France. He hypothesized that by exposing the inner ear muscles to modified high and low pitch frequencies, these muscles would habituate to sounds thus reducing auditory sensitivities (Tharpe, 1999). Berard developed a listening treatment protocol of modified music which he claimed would reduce auditory sensitivities, and in turn reduce negative behaviors associated with the misperception of sound (Tharpe, 1999).

Occupational therapist Sheila Frick's work followed the theories developed by Tomatis and Berard. Frick created the Therapeutic Listening® program designed for use as a complimentary intervention tool within clinic-based sensory integrative therapy (Hall & Case-Smith, 2007). This program involves listening to modified music through headphones while participating in motor activity. As the user habituates to the music, listening time is increased (*Vital Links*, n.d.).

Sheila Frick, Mary J. Kawar, and Ron Frick also developed an intervention tool designed for vestibular training for children called *Astronaut Training* (Kawar, Frick, & Frick, 2005). This program is a sound-activated vestibular-visual protocol for moving, looking and listening, and incorporates therapeutically imposed movement, visual (sight) and auditory (sound) activities that are fun and appealing to children. The program involves as series of therapist-directed preparatory, linear and rotary activities that provide sensory input to the child's visual, vestibular, proprioceptive, and auditory systems. Each Astronaut Training activity is individually tailored to each child's responses in order to monitor his or her responses to avoid sensory overload (Kawar, Frick, & Frick, 2005).

Inspired by Berard, Tomatis and Frick's Therapeutic Listening program connecting auditory and vestibular integration, in 2007, William P. Mueller introduced a supplementary series of interactive game products to his EASe audio CDs that incorporate a visual-vestibular sensory processing component (Mueller, 2010). Mueller's therapeutic games involve the child listening to modified music at the same time as they play a video game that is proposed to integrate visuo-vestibular environments with auditory stimulation.

Visuo-vestibular sensory processing refers to the interaction between the visual and vestibular sensory tracts, where visual information produces a vestibular head-righting response consequent to a body tilting (Mueller, 2010). In each EASe game, the child maintains control of his or her movement within the virtual environment by manipulation of the computer mouse, using his or her visual processing skills to search and locate designated items visible in the background. The background scene then moves relative to the child's manipulation and movement of the game piece. In other words, the mountains and trees appear to draw closer or further away based on directing of the game piece forward or backward. Additional distractions and environmental components, such as dust storms when in the desert, are designed to provide a sense of movement and to habituate the child to vestibular input (Mueller, 2010).

The EASe program of games and music CDs is based on years of extensive research on the auditory system, conducted by Mueller and his predecessors. The game developer has received numerous positive reports from families, therapists and teachers regarding the effects of the EASe program. The games and music CDs are currently used across the world as a complimentary therapeutic intervention tool for individuals with sensory processing deficits (Mueller, 2010). At this point in time, no other empirical studies have been conducted on the program's effect on audio-visuo-vestibular processing.

Problem Statement

Research has been conducted on the effectiveness of individual programs developed to address problems with either auditory, visual or vestibular sensitivities (Hall & Case-Smith, 2007; Biel & Peske, 2005). However, limited research is focused on the concurrent use of audio-visual-vestibular interventions to address sensory processing deficits (W. P. Mueller, personal communication, June 25, 2011). Research is needed on auditory-based interventions to explore the effects of an intervention tool, such as EASe, that combines virtual learning with auditory input to produce evidence for its use as a therapeutic intervention tool that can be used by occupational therapists. Limited research has been conducted on the effectiveness of the EASe program as a tool that can be used by occupational therapists to address attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing problems in the home environment.

Purpose Statement

The purpose this study is to explore the effect of Electronic Auditory Stimulation effect (EASe) games and music CDs on the visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing problems of 8-12 year old children who exhibit audio-visual-vestibular processing deficits. The research questions are: (1) Will the use of EASe games for 28 days, twice a day for thirty minutes improve a child's visual attention, spatial organization, and occupational performance, as measured by the Comprehensive Trail-Making Test (CTMT; Reynolds, 2002)? (2) Will the use of EASe games for 28 days, twice a day for thirty minutes improve a child's praxis, social participation, vision, hearing, touch, proprioception, vestibular function, and sensory processing problems, as measured by the Sensory Processing Measure-Home Form (SPM-Home; Parham & Ecker, 2009)? (3) Will the use of EASe games for 28 days, twice a day for thirty minutes improve social participation and behavior, as documented by clinical observations? The null hypothesis is: that the use of EASe games for 28 days, twice a day will not significantly improve a child's visual attention skills, spatial organization skills or occupational performance at home as measured by SPM-Home Form, CTMT, or EASe game tracking scores.

Significance

This study will provide preliminary evidence regarding the effect of the EASe games and music CD's on the visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, sensory processing problems, and occupational performance skills of children who exhibit sensory processing deficits. The study will offer quantitative evidence regarding the use of the EASe games as a therapeutic option for improving sensory processing skills.

Operational Definitions

For the purposes of this study, the following terms have been operationally defined for use within this study:

Auditory processing. The process responsible for conveying sound and attaching meaning to tone, pitch (acuity), and sound patterns (Russel & Nagaishi, 2005).

Electronic Auditory Stimulation effect (EASe). Audio CD's and interactive game products designed "to stimulate, challenge, and promote sensory processing in children on the autism spectrum and others experiencing difficulty with sensory processing and organization" (Mueller, 2010).

Occupational performance. The act of carrying out a desired activity that "results from the dynamic transaction among the client, the context, and the activity. Improving or enabling skills and patterns in occupational performance leads to engagement in occupations or activities" (AOTA, 2008).

Spatial organization. The ability to discriminate among objects, plan actions in relation to objects, determine the relative distance between objects, figures, landmarks, and determine the location of objects and settings and the route to the location (Schneck, 2005).

Semiparametric Ratio Estimator (SPRE). A unique statistical program that provides valid quantitative outcomes for occupational therapy treatment(s). SPRE is also able to predict future outcomes of occupational therapy services (Weissman-Miller, Shotwell, & Miller, 2011).

Vestibular processing. The process responsible for giving "information about the body's position in space, movement or lack of movement through space, and direction of movement" (Russel & Nagaishi, 2005, p. 828).

Virtual reality (VR). A computer-based technology that gives the user "opportunities to interact with virtual objects and events that appear, sound and, in some cases, feel similar to those of the real world." (Laufer & Weiss, 2011, p. 59).

Visual attention. A visual-cognitive component involving the selection of visual input that provides "an appropriate time frame through which visual information is passed by the eye to the primary visual cortex of the brain, where visual-perceptual processing can occur" (Schneck, 2005, p. 415).

Visual processing. The cognitive abilities used to take in visual information received about the environment through the eyes and organize, interpret and respond to it. (Schneck, 2005).

CHAPTER 2

LITERATURE REVIEW

Sensory integration is essential to children's ongoing development in critical life areas such as motor skills, praxis, and social skills (Ayres, 1972). As such, significant difficulties related to processing and integrating sensory information will have a major impact on a child's life if they are not addressed. This study aims to investigate the effect of the EASe program on auditory, visual, and vestibular function in children's (8-12 years) sensory integrative abilities. EASe interactive games and CDs are intended to help children habituate to sensory input by gradually exposing them to audio, visual, and vestibular inputs (Mueller, personal communication, June 25, 2010).

In order to accomplish this study, literature was reviewed from the following disciplines: occupational therapy, physical therapy, psychology, neurology, and education. Databases searched included Galileo, EBSCO Host, and the Cochrane Database. Search terms and phrases included: sensory integration, sensory deficits and children, sensory defensiveness and children, autism spectrum, learning disabilities, sensory deficits and effect on behavior, sensory processing and socialization, hyposensitivities, hypersensitivities, neurological studies on sensory systems, auditory therapies, sound therapies, vision therapy, virtual rehabilitation, and video games for use in therapy.

This literature review will cover topics crucial to this study beginning with concepts of sensory processing and sensory integration. It will examine the neurology of differences in sensory processing abilities in the general population. Next, the discussion will specifically address children who experience problems processing and/or integrating sensory information and for whom sensory sensitivities become problematic. Reactions to sensory stimuli, associated behaviors, and effects on occupation and family life will be discussed. A variety of occupational therapy approaches to address children's sensory-related problems will be reviewed. The Electronic Auditory Stimulation effect (EASe) program and its use of virtual reality and specially designed audio aspects will be described. Finally, the literature regarding specific assessment tools, namely the *Sensory Processing Measure*-Home Form (*SPM-Home;* Parham & Ecker, 2009) the *Comprehensive Trail Making Test* (*CTMT*; Reynolds, 2002), the *Sensory Integration and Praxis Test*-Vestibular Function Subtest (*SIPT-Vestibular Function Subtest;* Ayres, 1989), and clinical and parental observations will be discussed.

Sensory Processing Terminology

Sensory processing terms have been referred to in different ways by neurologists and occupational therapists and have evolved as new evidence is acquired. To reduce confusion, it is important that the field of occupational therapy employ a common terminology (Schaaf & Davies, 2010). Currently, the term Sensory Processing Disorder (SPD) is defined as "the diagnosis of a sensory-based processing challenge" (Miller, Anzalone, Lane, Cermak, & Osten 2007, p. 136), and encompasses a number of diagnoses including: Sensory Modulation Disorder (SMD), Sensory Based Motor Disorder (SBMD), and Sensory Discrimination Disorder (SDD). The use of this overarching term will help reduce confusion; however, sensory processing terminology will continue to change as new evidence is uncovered and new diagnoses are discovered (Miller & Lane, 2000).

Schaaf & Davies (2010) suggest that it is more appropriate to provide a descriptive statement of a sensory problem (i.e., children and adolescents with difficulty processing and integrating sensory information) rather than a name of a disorder (Sensory Integrative Dysfunction or Sensory Processing Disorder), as this reduces confusion when discussing several complex terms. This recommendation to describe sensory processing problems rather than associating individuals with disorders will be followed in this paper when possible (terminology within direct quotes will not be altered).

Audio-Visuo-Vestibular Triad

Sound is received by the ear and processed in the auditory ossicles, small bones in the ear named for their shape. The ossicles convert the sound from waves to mechanical vibrations in the ear (Bundy, Lane & Murray, 2002). Once the ossicles convert the sound, the mechanical vibrations then move to the cochlea and on to the nerve cells associated with hearing. The vibrations also travel through the semicircular canals, which function to maintain balance and are part of the vestibular system. The incoming sound passes through these organs and is then transmitted to the vestibular nucleus (VN) in the brainstem. Once in the brainstem, the sound is processed and sent to three different locations: first, to the lower centers of the brain which relay the incoming signal to the spinal cord motor neurons to stabilize posture; second, to the abducens nerve which functions to stabilize gaze and produces the vestibulo-ocular reflex; and finally, to the higher centers of the brain, which function to maintain spatial orientation in combination with the visual system (Bundy et al., 2002).

Visual input passes through the eye to the back where the retina, which consists of ganglion cells, is located. The ganglion cell axons form the optic nerve which passes to the brain's thalamus and continues on to the striate cortex where the complete retinal map exists. Three distinct anatomical pathways, which have separate functions, extend to the cortex where higher-order visual areas exist. These separate pathways process different types of visual feedback including the perception of: form and color, shape and depth, and spatial relationships and motion. These areas work interactively to achieve integration of visual information. This process likely occurs in several stages across the majority of cortical levels (Kandell, Schwarts, & Jessel, 1995).

Process of Sensory Integration

The neurosensory development of a child's brain occurs in a linear and sequential order (Liu et al., 2007). Children's primary sensory systems (audio, visual, and vestibular) continually develop throughout childhood and additional sensory systems form and connect to existing systems. Repeated exposure to sensory experiences as well as exposure to novel sensory experiences causes changes within one's sensory systems. As the brain takes in new sensory input and compares it to already existing sensory information, neural restructuring occurs. This process results in improved adaptive responses to one's environment over time (Parham & Mailloux, 2005). Rapid growth of various sensory systems occurs during critical periods throughout childhood. During these periods, the brain forms thousands of axonal and dendritic connections. The connections allow the brain to create memory and are influenced by activity input (Liu et al., 2007).

The vestibular system begins to develop in the womb in response to the mother's movements. Similarly, the mother's heartbeat stimulates growth of the auditory system. Depending on where and how the fetus moves in the womb, the sound of the mother's heartbeat increases or decreases in intensity (Parham & Mailloux, 2005). This relationship to movement initiates the growth of neural networks between the vestibular and auditory sensory systems (Russel & Nagaishi, 2005**)**. A child's visual system also begins to develop in the womb and forms connections to the existing auditory and vestibular systems. After birth, their visual system develops rapidly as the infant is exposed to the outside world (Kandell et al., 1995).

Observable actions children make in response to stimuli provide evidence that neural connections exist between the brain's sensory systems (Ayres, 2005). For example, when a child hears a loud noise they will turn their head towards the source of the sound, allowing their visual system to attempt to locate what is causing the sound. At the same time, the child's vestibular system helps them to maintain their balance as they move to adjust the position of their head and the posture of their body allowing them to stabilize their gaze. This reaction to an unexpected sound is known as the vestibulo-ocular reflex (Russel & Nagaishi, 2005).

Sensory integrative difficulties can develop at any point childhood according to each child's unique environmental circumstances. Such difficulties are often set in motion when children are overexposed or underexposed to sensory input during periods of rapid sensory system development in the brain. Improperly formed neural connections within and between children's sensory systems causes inappropriately leveled adaptive responses as well as further developmental delays (Russel & Nagaishi, 2005). Several studies have shown that when pre-term infants are exposed to unfavorable environments (e.g.: loud noises or bright lights) in the neonatal intensive care unit (NICU) their sensory systems are negatively affected. Symington and Pinelli (2009) conducted a review of 36 randomized-controlled trials regarding developmental care interventions in the NICU. The results of their research concluded that efforts to maintain a favorable environment for infants in the NICU benefit brain development of senses (Symington and Pinelli, 2009).

Researchers have found that newborn children in overcrowded institutions are often not held enough and the development of their proprioceptive systems is hindered. Touch deprivation resulted in increased morbidity rates for these infants whose basic nutritional needs were satisfied. Too much sensory input during critical periods is also detrimental to a child's development (Dunn, 2009). For instance, if a parent plays loud music while their baby is sleeps, their auditory system will become maladjusted. Further, when one sensory system is negatively affected, connected systems are also adversely impacted. An example is when an infant's visual system is over stimulated from frequent exposure to bright lights; their auditory system may show signs of decreased responsiveness (Liu et al., 2007). Gentle touch, positioning techniques, and modified exposure to light and sound all assist newborns in the development of properly functioning sensory systems (Hunter, 2005).

Research has found that children with sensory integrative difficulties interpret sensory inputs differently than the general population. Sensations which do not disturb the majority of the population may be disconcerting to children with sensory integrative problems. According to the sensory systems which are affected, different types of inputs will negatively affect these children (Ayres, 2005). For example, leaving the television on during conversation may be intolerable to children with significant auditory issues. Over time, children tend to avoid experiences which expose them to stimuli they perceive as noxious. This avoidance further strengthens existing faulty connections in these children's brains, exacerbating their sensory integrative difficulties (Eide, 2003).

Understanding how the brain's sensory systems operate helps guide occupational therapists' development of intervention techniques. Occupational therapists are able to help children integrate sensory information appropriately through grading sensory experiences which causes restructuring of the brain's sensory system connections (Pfeiffer, Koenig, Kinnealy, Sheppard & Henderson, 2011). As these new neural networks are reinforced, linked sensory areas also benefit, improving higher brain functioning over time (Russel & Nagaishi, 2005).

Sensory Integrative Abilities in the General Population

According to Parham and Ecker (2009), a conservative estimate is that approximately ten percent of the general population is affected by sensory processing disorders. A study conducted by Ahn, Miller, Milberger, and McIntosh (2004) found that at least 40% of general population has various degrees of difficulties processing sensory information. Ahn et al. (2004) conducted another study to determine what percentage of the population has sensory difficulties significant enough to qualify them as having a Sensory Modulation Disorder diagnosis. They found that 5.3% of their 703 participants, who were representative of the general population, would qualify as having sensory issues significant enough for diagnosis of a disorder (Ahn et al., 2004). A separate study which analyzed survey data led to a similar conclusion, that 5% of the general population is affected by significant sensory modulation difficulties (Miller, Anzalone, Lane, Cermak, & Osten., 2007). It has been speculated that as many as 20% of the general population is over-sensitive or ultra-sensitive to external sound (Mueller, 2010).

The impact on the lives of people who have diagnoses related to sensory system(s) malfunction is considerable (Koenig & Rudney, 2010), influencing the daily activities and occupations of each individual diagnosed. Researchers have found that "up to 30% of individuals with developmental disabilities also have Sensory Modulation Disorder" (McIntosh, Miller, Shyu, & Hagerman, 1999, p. 608). Rates of sensory processing disorders are high for children who already suffer from diagnoses such as: Autism, Schizophrenia, Attention Deficit Hyperactivity Disorder (ADHD), and Fragile X Syndrome (Dunn, 2001). Of these groups, children on the Autism spectrum are the most likely to have issues with processing sensory information. In fact, it is estimated that "39% of the children with autism spectrum disorder are under-reactive to sensation, 20% are hypersensitive, and 36% show a mixed pattern of hypersensitivity and hyposensitivity" (Case-Smith & Arbesman, 2008, p. 417).

Neurological Validation

Although occupational therapists and other practitioners apply Ayres' sensory integration theory in the treatment of children with difficulties in processing and integrating sensory information, her intervention methods have only recently been supported by neurological evidence. Functional neuroimaging methods, including electroencephalography (EEG) and event-related potentials (ERPs) have allowed for precise methods for the study of the electrical activity that occurs when the brain receives sensory input. Electroencephalography methods are excellent for studying the sensory systems as they directly measure brain activity (Davies & Gavin, 2007). They provide graphic displays of specific events by "time-locking the EEG to the occurrence of each event (e.g., the onset of sensory stimulus), creating segments around the event, and then averaging the segments of multiple presentations of the event." (Davies & Gavin, 2007, p. 177).

Neuroimaging has allowed researchers to identify areas of the brain that transmit sensory information such as "regions in the occipital cortex for vision, to regions in and around the superior temporal gyrus for audition, and to regions in the post-central gyrus for touch" (Maculoso & Driver, 2005, p. 264). Magnetic resonance imaging (MRI) has provided evidence that these sensory regions of the brain interact, also known as sensory integration. A recent study by Maculoso & Driver (2005) used functional magnetic resonance imaging to study the effects of sensory stimulation. The authors found that sensory brain areas that seemed unrelated to one another responded to an induced stimulus introduced by the testers that was unrelated to the function of that particular sensory system, suggesting that "remote regions of the brain can come to have a common spatial focus" (Maculoso & Driver, 2005, p. 264).

Neurological studies have been conducted which validate that the brain activity of children with sensory processing disorder diagnoses is in fact different from their peers in the general population (Eide, 2003). One such study by Davies and Gavin (2007) revealed that "brain activity as measured in two [event-related potentials] paradigms could be used to correctly classify children with Sensory Processing Disorder and distinguish them from a group of children who were typically developing with 86% accuracy" (Davies & Gavin, 2007, p. 188).

Another study by McIntosh et al. (1999), employed electrodermal activity (EDR) to measure participants' reactions to stimuli. A control group of 19 children was compared to a group of 19 same-sexed and similarly aged children who all had been diagnosed with sensory modulation disorder. EDR measurements were taken of the two groups to determine whether or not the experimental group was distinguishable from the typically developing group of children. The results showed that the electrodermal activity of the two groups was notably dissimilar; the children identified as having sensory difficulties responded less to sensation than children in the regularly developing group. When children with sensory related diagnoses *did* respond to the stimuli, it was to a greater extent and frequency than responses in the control group. The children within the sensory modulation disorder group who either under-responded or over-responded to the stimuli had more reactive behaviors than the control group (McIntosh et al., 1999). This study also supports Ayres' concepts that children with difficulties processing and modulating sensory information can be distinguished from the general population and that their abnormal brain functioning relates to under-responses and over-responses to sensory stimuli (Davies & Gavin, 2007).

Children With Sensory Difficulties

Dunn explains that "data from children and adults, persons with and without disorders, and out-of-laboratory and natural environment settings indicate that sensory processing has a pervasive influence on the human experience" (Dunn, 2001, p. 611). Behaviors associated with sensory sensitivities can impede performance of daily activities, academic skills, and social participation (Ben-Sasson, Carter, & Briggs-Gowan, 2009). It has also been shown that there are increased negative social and/or emotional implications over time for children who suffer from sensory-related diagnoses and who do not receive interventions (Cosbey, Johnston, & Dunn, 2010). According to Ben-Sasson et al. (2009), in a child with a sensory-related diagnosis, non-noxious stimuli might be interpreted as "harmful, painful, or distracting. Thus, the child is not able to habituate to the stimuli nor is able to function effectively in its presence" (p. 1). Possible reactions to these negative perceptions of stimuli include, "fear, avoidance, distraction, over-vigilance, and/or aggression especially when the stimulus is not self-initiated" (Ben-Sasson et al., 2009, p. 1).

Abnormal reactions and behaviors related to sensory difficulties often impact important childhood occupations. Primary roles for school-aged children include: being a friend, a student, a participant in play activities and a family member. Occupational performance in these areas is impacted by one's ability to adapt and respond appropriately to new experiences. One study found that behavioral consequences of misrepresented sensations, "disrupted practical day-to-day functions at home, in the classroom, and on the playground, affecting attention & arousal (hyperactivity or hypoactivity), movement, speech, balance, and auditory and visual perception" (Eide, 2003, p. 1). Research findings suggest that, "elevated sensory over-responsivity (SOR) behaviors can impede performance of daily activities, academic skills, and social participation" (Ben-Sasson et al., 2009, p. 1).

Contextual Influences on Sensory Processing Abilities

The environment plays a large role in a person's ability to cope with sensory information (Brown & Dunn, 2010). Eide (2003) suggest that children's sensory-related difficulties manifest differently according to their surroundings as well as their accumulated experiences throughout the day. Task demands vary according to one's environment (Eide, 2003).

School. School provides an optimal setting for children to socialize, form relationships with each other, and develop their social competency skills. The new and uncontrollable school environment places children in a situation where they are exposed to a tremendous amount of sensory input. Children with sensory related difficulties tend to have stronger negative reactions to stimuli to which they are not accustomed. For this reason, many children's sensitivities become more apparent when they begin to attend school (Eide, 2003). Children with these sensitivities are likely unable to avoid disconcerting sensations throughout the day and often have over-reactive responses to sensory input and external stimuli. For example, after his or her sensory threshold is reached, overhead lighting will irritate a child who has visual sensitivities. Similarly, cafeteria noise can be extremely challenging to handle for someone who is sensitive to noise. The reactive behaviors of a sensory-sensitive child are more readily noticed by school staff members who are familiar with appropriate behaviors for the various age groups (Ben-Sasson et al., 2009).

School age children often do not have an option to eat their lunch anywhere other than a brightly lit and noisy cafeteria where other classes are constantly entering and leaving according to their lunchtimes. Eide (2003) suggests that children with sensory sensitivities that are overwhelmed by any or all of these stimuli will likely attempt to block out the scene taking place around them and subsequently miss out on socialization. Efforts to protect themselves from sensory overload are very tiring and often cause these children to be anxious and irritable. Children with sensory sensitivities may be able to control themselves during the school day but then take out their frustrations on their loved ones when they return home from school (Eide, 2003).

Learning is frequently impacted by children's difficulties processing and integrating sensation. At school, children experiencing sensory sensitivities often have difficulty keeping to a task. This includes "writing requirements of the classroom (problems of quantity as well as quality), mental & physical distraction or fatigue, and clumsiness and difficulty following instructions" (Eide, 2003, p. 1). Children who are over-sensitive to external stimuli often tire as a result of their defensive efforts to tune out "overbearing" sensations.

Conversely, sensory-seeking children may not have enough stimulation to maintain their alertness throughout the school day and their inattentive state is interpreted by teachers as lack of interest. Another common scenario is that these children are more active than is acceptable inside the school in an attempt to get the sensory input that they crave (Eide, 2003).

For children with sensory deficits, sensitivities differ from day-to-day which creates confusion for school staff who may not understand the complexities of sensory processing-related diagnoses. Children's academic skills and behaviors fluctuate along with these variations. Teachers may misinterpret the negative behaviors associated with children's sensory difficulties as being under the child's control. Teacher reports of unexpected academic performance and/or maladaptive behaviors raise parents' awareness that there is a problem (Ben-Sasson et al., 2009).

Play. All children are naturally motivated to play, but they choose activities according to their capabilities and sensitivities. As such, play is another main childhood occupation where children's difficulties with sensation manifest. A recent study examined the relationship between children diagnosed with Sensory Processing Disorder and the occupation of play. The researchers examined how much children with SPD diagnoses play compared to their peers. The hypothesis of the study was that due to the high degree of sensory input and associated challenges play involves, the children with sensory issues would play less than their peers (Bundy, Shia, Qi, & Miller, 2007).

The results of Bundy et al.'s study were surprising: both the control group and the group with sensory processing deficits were found to be "extraordinarily playful" (Bundy et al., 2007, p. 205). Most often the children with sensory processing disorders chose sedentary activities, which require less interaction, movement, and coordination, rather than participating in interactive play. Despite their sensory challenges, by choosing play activities that matched their abilities and sensitivities, the children with sensory diagnoses were able to spend the same amount of time playing as the control group (Bundy et al., 2007).

A. Jean Ayres also observed that sensory problems affect children's play choices. She noted that children with dyspraxia tend to avoid participating in activities which require motor planning, and those with tactile defensiveness avoid activities (Ayres, 1972). An earlier study by Harkness & Bundy (2001) involving children with physical disabilities found that these children scored unexpectedly high in displays of "mischief and teasing [sedentary activities] closely aligned with clowning and joking" (p. 206).

Children with sensory difficulties tend to have immature play patterns which "are associated with poor peer acceptance and poor social competence" (Cosbey et al., 2010, p. 462). As the brain develops, maps can be modified based on the activities in which the person chooses to engage. By choosing these "sensory-safe" play activities, children are avoiding the types of sensory input they need most (Dunn, 2001). As a result, over time they fall further and further behind their peers in areas in which they are already weak (Cosbey et al., 2010).

Home and community. A child's difficulties in processing and integrating sensory information may affect their family life (Eide, 2003). Not only do parents of these children have to contend with their child's unpredictable moods at home, the family may not be able to all go out together to places which will likely bother their child. If the family does attempt to spend time out away from home, an underlying anxiety often accompanies them as they wonder whether or not their child will have a public display of negative behavior. Parents also may not want to take their child on a quick trip to the grocery store. The car ride may make the child feel car sick and the grocery store may be overwhelming resulting in negative behaviors. Parents and siblings may become frustrated or angry with the child affected by sensory issues, particularly if the family does not understand why their loved one is being difficult (Eide, 2003).

Assessment of Sensory Processing

When parents realize that their child with sensory processing deficits is having difficulties with various childhood occupations such as play and social behavior (Ayres, 1972), they often consult their pediatrician who refers them to occupational therapy. Occupational therapists use a variety of assessments to evaluate a child's visual, vestibular, and auditory skills (Spitzer et al., 1996). Assessment results help the therapist and family to determine an intervention plan to best address area(s) of need (Case-Smith & Arbesman, 2008). When the assessment results show significant differences in integrating and modulating sensory information, many families are relieved to learn that there is a reason behind their child's difficulties. The parents may modify and regulate their child's home environments to avoid over and under stimulation and inform teachers of any preferences which will increase the child's ability to perform well in school (Eide, 2003).

Assessment Tools

The following is a description of assessment tools used by occupational therapists to assess visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, sensory processing problems, and occupational performance skills:

Sensory Processing Measure (SPM). The Sensory Processing Measure (SPM-Home; Parham & Ecker, 2009) is a norm-referenced assessment which "enables assessment of sensory processing problems, praxis, and social participation." The SPM consists of three forms: "the Home Form, the Main Classroom Form, and the School Environments Form" (p. 3). It provides information on the sensory functioning of children ages 5 through 12 years in grades kindergarten through sixth.

The SPM-Home Form consists of 75 items regarding children's sensory processing abilities in their home setting. This form is considered by most parents to be easily completed within approximately 15 minutes. The results of the SPM-Home Form provide eight different standard scores: Social Participation, Vision, Hearing, Touch, Body Awareness (Proprioception), Balance and Motion (Vestibular Function), Planning and Ideas (Praxis), and Total Sensory Systems. These scores fall into the three interpretive categories of Typical, Some Problems or Definite Dysfunction (Parham & Ecker, 2009).

Comprehensive Trail-Making Test (CTMT). Trail-making tests have long been used for the diagnosis of various kinds of neurocognitive dysfunction (Lezak, Howieson, & Loring, 2004). The most commonly used of these is the *Comprehensive Trail Making Test* (CTMT; Reynolds, 2002). The CTMT is a standardized test consisting of five visual searching and sequencing tasks, requiring the participant to connect a series of stimuli in sequential order as quickly as possible. The test is designed to measure divided attention, concentration, resistance to distraction through tasks that involve visuospatial tracking, and cognitive flexibility (or set-shifting), while remaining sensitive to difficulties with attention and the effects of brain injury (Smith et al., 2008).

Norms set for the CTMT are included for participants between the ages of 8 years, 0 months and 74 years, 11 months. Scoring is calculated based on total length of time for completion of each trail, which includes time taken for any mistakes. The CTMT also provides information on the kinds of distractions that might serve as problematic for the given participant, as well as their processing speed over the course of each trail (Smith et al., 2008). Standardized or scaled scoring is provided in the form of normalized T-scores for each trail and for composite scoring, each with a mean of 50 and a standard deviation of 10, as well as with accompanying percentile rankings (Reynolds, 2002).

Sensory Integration and Praxis Test (SIPT). The Sensory Integration and Praxis Test (SIPT; Ayres, 1989) is an observation-based standardized test. For this reason, it is meant to be used only by experienced and specially trained practitioners to measure strengths and weaknesses in children's sensory abilities. It is considered both reliable and valid. The SIPT includes 17 subtests which provide therapists with specific information for multiple areas of sensory function for children aged 4years to 8 years 11 months. Sensory areas measured include: vestibular processing (including balance), various somatosensory functions, bilateral coordination, sequencing, praxis, and visual form and space perception (Mailloux et al., 2011). Individual tests within the SIPT take about 10 minutes to complete, but the entire battery requires approximately two hours of administration time (Ayres,1989). The SIPT assessment in its entirety was not chosen for use in this study, as the focus of the study is not on classic Sensory Integration. Yet one component of the SIPT, nystagmus or the oculomotor reflex, was chosen to assess vestibular function, as this is one of the related concerns of the study.

The vestibular function subtest of the SIPT uses post-rotary nystagmus (PRN) testing to measure vestibular functioning (Mailloux et al., 2011). Nystagmus is an involuntary movement of the eyes, where the eyes appear to be oscillating. Post-rotary nystagmus is the involuntary oscillation of the eyes after rotations (Hertle, 2008). In this subtest, the duration of post-rotary nystagmus is timed and recorded. Intervention is deemed to be effective on vestibular function if pre-intervention timing scores of PRN have decreased in post-intervention measurements.

Clinical observations. Clinical observations are an important piece of the overall assessment of children's sensory processing abilities. Any unusual reactions and behaviors which occur during an occupational therapy session should be noted by the occupational therapist. For example, if a child has demonstrated willingness to engage in a game on the trampoline, but suddenly refuses to jump, this might indicate changes in the sensory processing systems of the brain. Clinical observations allow therapists to track behavioral changes over time in the child's sensory reactions and serve as supplemental documentation for standardized assessments (Sames, 2005).

Occupational Therapy Interventions

Based on assessment results of each client's strengths and deficits, as well as information gained from his/her narrative, the occupational therapist will design an individualized intervention program (Polatajko & Cantin, 2010). Pediatric occupational therapists employ a wide variety of intervention approaches to address the complexities and effects of sensory issues. According to Parham and Mailloux (2005), occupational therapists should use a client-based approach for any chosen intervention, as the ultimate goal is to improve children's quality of life. Such a practice entails consideration of areas of occupation and specific goals which are most important to each child and their family.

Areas of occupation include: activities of daily living (ADLs), instrumental activities of daily living (IADLs), rest and sleep, education, play, leisure, and social participation. Additionally, a practitioner must consider client factors, relevant performance skills and patterns, specific activity demands, and finally context and environments as they all can affect a child's performance (*Occupational therapy practice framework: Domain & process*; The American Occupational Therapy Association, 2008).

The sensory integrative approach has gained popularity in recent years. It is based on the premise that appropriately graded sensory experiences improve sensory integration which leads to desirable adaptations and behaviors (Parham & Mailloux, 2005). Sensory integration (SI) theory continues to evolve over time as "theoretical paradigms are modified and adapted to capture and describe new findings, integrate them with existing knowledge, and classify them in ways which will guide practice and research" (Schaaf & Davies, 2010, p. 363).

Parents have contributed "ardent testimonials that occupational therapy with sensory integration approaches improves quality of life for their family" (Cohn, Miller, & Tickle-Degnen, 2000, p. 37). Though much anecdotal evidence of positive outcomes has been reported by clinicians and families in regard to sensory integrative therapy, neurological support for the basic principles of this intervention was not possible until the 21st century (Davies & Gavin, 2007). Barenek (2002) also noted that although sensory integrative interventions seem to result in positive improvements in children's behaviors and social participation, empirical evidence supporting the effectiveness of SI interventions continues to be weak.

Research supports the use of family-centered, interdisciplinary approaches. A literature review conducted by Case-Smith & Arbesman (2008) found, “strong positive evidence for occupational therapists to use comprehensive, individualized analysis of the child’s performance to develop the intervention strategies” (p. 427). The Individuals With Disabilities Education Act of 1990 also acknowledges the “family-centered care for children and families with special health care needs” in successful intervention (Cohn, Miller, & Tickle-Degnen, 2000, p. 36).

Based on their research on client/family-centered care, Cohn, Miller, & Tickle-Degnen (2000) advise that therapists avoid making assumptions about families’ values and priorities. An important aspect of client-centered practice when treating children is being aware of family member’s perspectives and communicating that these perspectives are valued. Such collaboration will lead to interventions that are well-suited for each family’s circumstances and needs. Children with sensory difficulties exhibit their own set of unique circumstances and needs in a variety of settings. As such, “best [occupational therapy] practice includes direct treatment to ameliorate sensory processing impairments combined with home, school and community intervention” (Miller, 2003, p. 1). Cohn, Miller, & Tickle-Degnen (2000) have made suggestions for future research needs based on their findings. It has been suggested that future researchers, “examine the ways in which sensory processing, occupational performance, and performance contexts influence each other and how changes in one domain may or may not lead to changes in another domain” (p. 42).

Occupational therapists commonly combine sensory integration with interactive play activities in order to individualize therapy sessions. The occupation of play is an important part of childhood and has been validated by the American Occupational Therapy Association (AOTA) as an appropriate context for intervention (Cosbey et al., 2010). The focus of these sessions is geared to address issues in the client's life to enhance their occupations of play and social participation. Such sessions can be described as relationship-based interventions where the occupational therapist is using the therapeutic relationship with the child to address their social-emotional growth (Case-Smith & Arbesman, 2008).

According to needs and circumstances of each child during sensory integration sessions, the occupational therapist may provide the child with positive feedback and guidance using cues and prompts. The occupational therapist will help to establish and encourage social environments that will promote success for children and model the positive effects of having friendships. The clinician may facilitate peer interactions in the clinic or during a home visit (Parham & Mailloux, 2005). Relationship-based interventions which use a sensory integrative approach such as these are often used with children with Autism Spectrum Disorder (Case-Smith & Arbesman, 2008). A variety of complimentary therapeutic intervention tools have been developed using the sensory integrative approach, specifically by use of virtual learning and other auditory-based interventions.

Virtual learning. Virtual reality (VR) training has been used in several populations with conditions ranging from Acquired Brain Injury (ABI)/Traumatic brain injury (TBI), Stroke, Multiple Sclerosis (MS) and Pediatrics, and can be used as an adjunct to sensory integrative approach in therapy. For example, vestibular difficulties, such as postural sway, are often caused by lesions on one side of the brain which may result from stroke or other head trauma. Such unilateral hemispheric damage causes the body to sway abnormally in the direction of the lesion. The virtual reality environment induces the optokinetic reflex in users, meaning that even if they are not moving; their eyes are able to follow a moving target. Ohyama, Nishiike, Watanabe, Matsuoka and Takeda (2008) hypothesized that the optokinetic stimulation provided by virtual reality would benefit people with vestibular related difficulties. They found that such stimulation causes people to lean in the direction of the moving object or reduce nystagmus, even when the stimulus is on the opposite side of the lesion. As such, the researchers concluded that "Virtual reality promises to rapidly improve ocular and locomotor deviation in patients with vestibular defects" (Ohyama, Nishiike, Watanabe, Matsuoka, & Takeda, 2008, p. 1213).

Fong, Chow, Chan, Lam, Li, Yan, and Wong (2010) suggest virtual reality can be classified in two categories consisting of full immersion or non-immersive virtual reality. Full immersion allows the individual to view themselves and or an avatar within the three-dimensional environment using head-mounted devices or a virtual prototyping or drafting table style device. Non-immersive allows the individual to interact with a virtual world by a computer screen with or without interface or head-mounted devices.

Fong et al. (2010) studied also report virtual reality provides the chance for intense repetitive practice of meaningful activities with augmented feedback for rehabilitation in a manner that can be more motivating than traditional therapy. It provides a safe environment and places no physical restrictions upon participants. Modification to change levels of difficulty in virtual reality can be easily done even though it may not be a realistic scenario. Additionally, it provides advantages over regular computer-based teaching programs by being able to "address real-time aspects of information processing and enhance dynamic interaction" (Fong et al., 2010 p.2).

Fong et al. (2010) studied twenty-four participants with Acquired Brain Injury (ABI) in the community. Their results of the study suggest that task-specific training through the use of non-immersive virtual reality automated teller machines (ATMs) versus six one-hour computer-simulated training could improve representative functioning and problem-solving in clients with

Acquired Brain Injury (ABI; Fong et al., 2010). These researchers proposed this type of virtual reality training may be used in multiple phases of problem-solving skills training, which ultimately can be used to solve problems in real life situations. They concluded that virtual reality ATM training was reliable in assessing occupational performance skills of individuals with ABIs. They also reported that this method is a valid assessment tool for screening and training of individuals with ABIs who are likely to have difficulties using real ATMs.

An additional study, conducted by Parsons and Rizzo (2008), reported that several virtual reality applications have been examined that analyze component cognitive processes including attention processes, spatial abilities, memory, and executive functions in persons with diagnoses such as stroke and multiple sclerosis (MS). Parsons and Rizzo (2008) investigated the use of full virtual reality immersion in thirty (15 males and 15 females) healthy participants ranging in age from twenty-one to thirty-six years to determine correlations between traditional neuropsychological measures and the use of a designed Virtual Reality Cognitive Performance Assessment Test (VRCPAT) that measures memory. The study's results concluded that both the traditional tests used to examine memory and the VRCPAT had a significant correlation. Parsons and Rizzo (2008) further state that continued research must be conducted to validate assessment tools in a larger group sample that include both memory impaired and non-memory impaired participants.

As summarized by Strickland, Marcus, Mesibov, & Hogan (1996) virtual learning allows individuals to discover new ways of responding and learning through computer-generated real life experiences. Strickland et al. (1996) suggest that virtual learning may be beneficial to individuals with Autism Spectrum Disorders (ASDs), stating that many children with ASD demonstrate sensory sensitivities and stimulation in certain settings may be overwhelming and result in behavior deterioration (Strickland et al., 1996). The virtual environment provides a controlled setting which can be monitored and adjusted based on children's sensory needs (Strickland et al., 1996).

Strickland et al. (1996) explain that specific stimuli can be elicited within virtual learning programs and that the amount of exposure is able to be controlled by the participant. For example, virtual learning allows for continuous readjustments to accommodate the needs and skills of the participating individual (Strickland et al., 1996). Researchers conclude that virtual learning makes generalization of results easier because of the realism it brings to the treatment intervention, as it is individualized. Virtual reality-based intervention research supports the growing evidence for use of computerized instruction for children with developmental disabilities (Strickland et al., 1996).

Another variation of virtual learning has been investigated by Mineo, Zeigler, Gill, and Salkin (2009). Researchers conducted a study that analyzed the engagement of four electronic screen media interventions: animated video, video of self, video of a familiar person engaged with an immersive virtual reality (VR) game, and immersion of self in the VR game in children with Autism Spectrum Disorder. The use of key boards, mice, and a media screen employ graphical environments, sound systems, head mounts, and immersion video, which all transmit and receive data to generate a sensory response.

There are several benefits of using virtual reality as an intervention. Mineo et al. (2009) explain that using virtual reality allows for instructions to be delivered with consistency, and for the game to be repeated an indefinite number of times without loss of fidelity. They further suggest that virtual reality offers experience to simulate real life situations that may be too dangerous to implement in real life. Mineo et al. (2009) conclude that the results of their study demonstrated greater duration of engagement visually and increased vocalization of children on the Autism Spectrum disorder using immersion of virtual reality versus traditional video screen media and that further research is needed to determine if learning and generalization of new skills are impacted in a positive way.

Virtual reality-based rehabilitation designed specifically for children is relatively new, resulting in minimal available research regarding its effects at this point in time. A current systematic review of literature by Laufer & Weiss (2011) pertinent to this study examines available research of VR used as a rehabilitative treatment for children. The conclusions of Laufer & Weiss's (2011) review support the conclusions of Mineo et al. (2009). These reviewers affirm that this type of therapy is reliable, safe, and has great potential as a treatment modality. These positive remarks are followed with the cautionary message that "higher quality research is necessary before the value of VR in pediatric rehabilitation truly can be ascertained" (Laufer & Weiss, 2011, p. 70).

Auditory-based interventions. Many alternative [sensory integration] based methods and programs have been developed in the past decade which provide specific sensory stimulation," including weighted vests and sound therapy programs (Polatajko & Cantin, 2010, p. 417). In the mid 1900's, Alfred Tomatis began experimented the effect of modified music on adults and children with an array of disabilities such as attention deficit disorder and learning disabilities (Hall & Case-Smith, 2007). Trained as a physician, Tomatis believed that the ear acted as a gateway to the nervous system. Tomatis's research led him to recognize the neurological link between the ear and the larynx, and noted that changes in a person's voice affects that person's hearing and vice versa. He purported that the input of modified music through the listener's ear retrains the auditory system to correctly perceive sound. Tomatis also claimed that by reducing auditory sensitivities, vocal emissions would improve and negative behaviors would decrease. His theories and their application are known as The Tomatis Effect (Dawson & Watling, 2000).

Dr. Guy Berard, an ear, nose, and throat physician who worked with Tomatis, pioneered the first auditory integration training (AIT) treatments at his practice in France. Berard's treatment program purports to produce results similar to those achieved by The Tomatis Method, but in less time, using a device known as the Audiotone Enhancer. He postulated that by exposing the inner ear muscles to modified high and low pitch frequencies, these muscles would habituate to sounds thus reducing auditory sensitivities. Much of Berard's research was focused on auditory stimuli's impact on language and behavior (Tharpe, 1999).

There has been much controversy over Auditory Integration Training (AIT) and its efficacy due to a lack of supportive empirical evidence. A review of the available literature on Auditory Integration Training (AIT) found 23 of the most credible studies had positive results as compared to three far less credible ones reporting no benefits from AIT (Rimland & Edelson, 2011). Nonetheless, a double blind study conducted by Zollweg, Vance, and Palm (1997) of 30 individuals with multiple disabilities was conducted over a ten day treatment period. Initial audiograms were provided, when available, by the patient. Subjects were tested at intervals over the course of 9 months using audiometry and the Aberrant Behavior Checklist, otherwise known as the ABC (Zollweg, Palm, & Vance, 1997). The authors compared pre-intervention and post-intervention data and found no significant difference in audiometry reports (audio threshold or loudness); however, there was a slight improvement in behavior as noted by the ABC (Zollweg, Palm, & Vance, 1997).

As a follower of both Berard's and Tomatis's work, occupational therapist Sheila Frick recognized that proper functioning of the auditory and vestibular systems is vital to overall sensory integration. Frick designed the Therapeutic Listening® program to address sensory issues such as auditory defensiveness and Central Auditory Processing Disorder (CAPD) using theories proposed by Berard and Tomatis (*Vital Links*, n.d.). CAPD is associated with difficulties in perceptual processing of auditory information, as demonstrated by poor performance in one or more of the following skills: sound localization and lateralization, auditory discrimination, auditory pattern recognition, and temporal aspects of audition. Difficult performance problems include temporal resolution, temporal masking, temporal integration, temporal ordering, auditory performance decrements with competing acoustic signals, and auditory performance decrements with degraded acoustic signals (ASLHA, 1996). Frick's listening program was designed for use in the home environment as a supplement to clinic-based sensory integrative therapy (*Vital Links*, n.d.). The theory is that children will benefit from the modified music during motor activities in order to increase their arousal, spatial organization, and self-regulation (Bundy, Shia, Qi, & Miller, 2007; Hall & Case-Smith, 2007).

The Therapeutic Listening® program requires clients to use stereo headphones for listening to electronically altered music while participating in motor activity for thirty minutes two times each day for a period of approximately three months. As the user habituates to the music, listening time is increased. This collaborative practice simultaneously stimulates the auditory and vestibular sensory systems. Currently the program offers 14 distinct compact disks ranging in musical types (e.g. symphony and nature), high and low tones, and beats, the first four of which were developed by Bill Mueller, creator of EASe products. Along with the use of this specialized music during classical sensory integrative treatments in the clinic, occupational therapists choose audio selections to best meet each client's needs and teach families how to implement Therapeutic Listening® at home. The music may be changed according to each client's progress gauged by his or her ability to integrate sound, as demonstrated by habituation of sound through sound localization and lateralization or other auditory processing skills (*Vital Links*, n.d.).

In addition to the Therapeutic Listening® Program, Mary J. Kawar, Sheila Frick, and Ron Frick (2005) developed a child friendly approach to vestibular training called *Astronaut Training: A sound activated vestibular-visual protocol for moving, looking and listening*. This program incorporates therapeutically imposed movement, visual (sight) and auditory (sound) activities that are fun and appealing to children. Astronaut Training is the term used to describe their treatment protocol for vestibular habilitation. The program is reported to be effective with all ages and involves as series of therapist-directed preparatory, linear and rotary activities that provide sensory input to the visual, vestibular, proprioceptive, and auditory systems Kawarr, Frick & Frick, 2005).

Each Astronaut Training activity is individually tailored to each child's responses in order to monitor his or her responses to avoid sensory overload. The therapist follows specific Astronaut Training guidelines to guide the child through a series of steps involving preparing for rotary and linear activation. Rotary activation is achieved with the child in sitting and side-lying positions on a special rotation board. Eye movement activities include rapid and slow horizontal and vertical saccades, pursuits, and vergence movements as well as peripheral and eye teaming activities (Kawar, Frick & Frick, 2005).

The developers of the Astronaut Training Program recommend that, over time, the therapist present the child with structured opportunities to experience linear, tilting, rolling, inverted, and rotary vestibular activities to extend the therapeutic effects of integrating visual, vestibular, and auditory sensory input (Kawar, Frick, & Frick, 2005). Though limited empirical evidence supports the use of Therapeutic Listening and the Astronaut program, over 5,000 occupational therapists have received Therapeutic Listening training since it became available in 1997 (Hall & Case-Smith, 2007).

An additional complementary tool developed in the late 1990s is the Electronic Auditory Stimulation effect (EASE) program, which combines virtual learning with auditory input for improving sensory processing abilities in children. While no known research studies have previously been conducted on the EASe program, it is the first to incorporate auditory, visual and vestibular processing within one game to help the child's brain integrate information from these systems more effectively (Mueller, 2010).

EASe Audio and Interactive CDs. The Electronic Auditory Stimulation effect (EASe) products, designed by William (Bill) P. Mueller of Vision Audio, is a virtual reality intervention developed to "stimulate, challenge, and promote sensory processing and organization" (Mueller, 2010). The following information was gleaned from email correspondence with the creator Bill Mueller during the months of May and June, 2011, unless otherwise indicated. All of the EASe game products provide interactive, non-testing environments, where the player is always in control of his or her movement through the world displayed on the screen (Mueller, 2010).

The EASe games are easily accessible to practitioners and families (Mueller, 2010). Cohn, Miller, & Tickle-Degnen (2000) reminds therapists that intervention will be effective if it is "sustainable within the contexts of family life". The EASe games program allows for home-based treatment which necessitates family participation and support. The accessibility of EASe products have led to its use by tens of thousands of parents, therapists, teachers, non-profit organizations, and school systems all over the world (Mueller, 2010).

The EASe program consists of 10 therapeutic music CDs and 6 interactive games, including Fun House Treasure Hunt, Off-Road, Snowmobile, Airshow, UFO, and Rover. The interactive games are composed of modified music played during a video game that is proposed to integrate virtual visuo-vestibular environments with auditory stimulation. The EASe Off-Road game is a unique multi-modal tool disguised as a video game (Mueller, 2010). It was designed to stimulate and challenge the virtual-vestibular, visual, and auditory triad of sensory pathways to promote appropriate response to sound and reinforce balance. The EASe Off-Road, Snowmobile, and Rover are identical games, with the exception of the environment setup and accompanying music, which is encoded exactly the same way but with different songs. (Mueller, 2010).

The EASe Fun House Treasure Hunt game, Vision Audio's most recently released product, reinforces organization and attention, incorporating auditory processing by encouraging the child to listen and follow verbal directions. It also serves to promote visual processing by providing on-screen directions to scan the displayed environment to locate and collect the indicated letters, words, faces and objects. The objective of all EASe interactive games is the same—to locate and clear as many objects (balloons, targets or other) as possible, as quickly as possible. Participants are encouraged to wear headphones while using the products, for enhancement of the virtual experience.

Throughout each game, the attention of the participant is captured with an object in motion within the object list at the top of the screen (object becomes larger and moves to the center of the screen), providing visual instruction to find and tag the object. Simultaneous verbal instruction is provided to direct the participant (e.g., "Find the yellow cube"). If the participant locates the incorrect object, a verbal correction is given (e.g., "That is a red ball, find the yellow cube"). Once the participant finds the correct object in the scene and tags it successfully, a bright visual fireworks of affirmation is displayed along with an auditory reward. Additionally, when a group of objects has been cleared, a further verbal reward is elicited such as, "You're so good at this!" (Mueller, 2010).

An additional element of the games is the visual challenge. Objects are displayed in the far field, or background and the participant must overcome distractions in the near field, or foreground, to reach them. This aspect of the game requires a degree of concentration and intention to complete successfully. The distractions are provided by a variety of methods, including smoke, bushes, flowers, clouds, balls, blocks, and other collectibles in Fun House and Off Road Treasure Hunts. Each game also has a timer and display showing the number of tagged objects and navigation aids in the form of maps, speedometers and air speed indicators. These applications serve as both assistant technologies as well as distractions (Mueller, 2010).

Mueller (personal communication, June 25, 2011) suggests that both the EASe Fun House Treasure Hunt and EASe Off-Road Treasure Hunt provide an additional "A-B-A discrete trial training segment in the form of a Treasure Hunt," where objects alternate between distractions and items for which the participant searches. The determining factor between distractions versus items of pursuit is the visual and verbal instructions provided in the header. In addition to displaying the score on-screen, these two games also store the name of each player and the time it takes a player to clear each group each time the game is played in his or her name (Mueller, 2010).

Mueller also developed ten EASe music compact discs (CDs) which can be used as a therapeutic supplement to or independent of EASe interactive games. The CDs are numbered 1 to 10, with no numerical value associated with level of difficulty. They were designed to train the listener with auditory sensitivities to cope with noise. The CDs provide variety within the listener's program to try to prevent loss of interest, as well as to promote flexibility within the protocol of the program based on the desires of the participant. When combined with the use of the EASe interactive game protocol, EASe music CDs provide an alternative method for exposing the participants to the key auditory elements included in the games and program. In fact, the objective of the games is to occupy the child with fun and stimulating visual challenges to accompany listening to EASe music (Mueller, 2010).

The EASe interactive games involve all three of the visual, auditory, and vestibular systems. A perfect balance of visual and auditory sensory information is provided to the player, so that the child does not initiate a fight-or-flight response due to existing sensory defense mechanisms (W. P. Mueller, personal communication, May 2011). The EASe games are uniquely designed to provide short bursts of sensory input, for example a tumbling experience, so that the brain can gradually adapt to this sensory input (W.P. Mueller, May 2010).

The vestibular aspect is also incorporated through auditory input of the coded music, which stimulates an optokinetic illusion where the player responds as though he or she is actually a part of the virtual environment. The optokinetic reflex is what allows the eye to follow objects in motion when the head remains stationary, also known as optokinetic nystagmus. Optokinetic illusion is when an fabricated outside stimulus specifically designed to trigger this reflex elicits a vestibular response in an individual. Optokinetic illusion and optokinetic nystagmus are human psycho-physiological responses to the same optokinetic stimulus, although illusion response is more stable than nystagmus response in higher intensity ranges of vestibular stimulation. (Shi, Wang, Ren, Miao, & Huangfu, 1998).

Sensory Integration (SI) theory suggests that sensory input from EASe interactive games will provide the player's central nervous system (CNS) with the appropriate amount of feedback needed for sensory integration (Roley & Jacobs, 2009). As play time (sensory intervention) accumulates, the plastic brain reorganizes itself (Farber, 1989). Neural connections between sensory systems in the brain strengthen and neural impulses travel faster, more often and with increased efficiency. Communication between neural sensory networks also improves. The result is sensory integration and so responses to sensory input in the future become more appropriate (Roley & Jacobs, 2009).

Summary

The researchers explored literature from multiple disciplines including occupational therapy, speech therapy, physical therapy, psychology, neurology, and education. Following a review of the literature regarding sensory processing deficits involving auditory, visual, and vestibular sensory input, and target-specific therapeutic interventions, the researchers determined there is a need for exploration of the effects of the EASe audio and interactive CDs with children who exhibit problems in visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing problems. This research will determine the effect of playing EASe games on children who exhibit visual, spatial, and resultant occupational performance problems. Additionally, the research will provide occupational therapists with evidence for making evidence-based recommendations regarding the use of this intervention tool for children at home and in the clinic.

CHAPTER 3

METHODOLOGY

Purpose

The purpose this study was to explore the effect of Electronic Auditory Stimulation effect (EASe) games and music CDs on the visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing problems of 8-12 year old children who exhibit audio-visual-vestibular processing deficits. Information gained from this pilot study will benefit occupational therapists and related professionals, their clients and families by providing evidence on the efficacy of the EASe program when used as therapeutic tool to improve visual, auditory, and vestibular skills in children.

In this study, the researchers hypothesized that the EASe games and music CD's would improve the child participant's visual attention, and task sequencing, as measured by lower scores on the Comprehensive Trail Making Test (CTMT; Reynolds, 2002), after 28 days of exposure to the EASe products, and social participation, vision, hearing, touch, body awareness, vestibular function, planning, as measured by lower scores on the Sensory Processing Measure-Home Form (SPM-Home; Parham & Ecker, 2009) after 28 days of exposure to the EASe products.

Research Design

This was a pilot study using an exploratory, quantitative research design. A convenience sample of thirty children from two clinics in the Metro Atlanta and North Georgia Region were assigned to two groups. Letters of authorization from both facilities were signed (Appendices A and B). Each group of children played a type of virtual computer game called EASe Fun House and EASe Off Road for 30 minutes twice daily for 28 days. One group began a 14-day trial with the EASe Off Road game and the other with the EASe Treasure Hunt game. After 14 days of game play each group played the alternate game for an additional fourteen days to complete twenty-eight days of game play. Each group was also assigned EASe music CDs, CD 1-shaping clouds and CD 2-in the sky for participants who were unable to tolerate game playing.

The Independent variable was identified as the Day of game play, within which each child had the potential to complete two game sessions, so long as the sessions were 3 hours apart. Each child's scores from the two daily sessions were averaged with respect to the number of minutes played per session to calculate that child's EASe Proficiency Score. The Dependent variable was identified as the outcome, which was the time it took for the child to move through particular levels in each game.

Questions guiding research. This study was aimed to determine the following questions: Will the use of EASe games for twenty-eight days, twice a day for thirty minutes improve a child's visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing skills, as evidenced by lower scores on the Sensory Processing Measure-Home Form (SPM-Home; Parham & Ecker, 2009) and lower scores on the Comprehensive Trail Making Test (CTMT; Reynolds, 2002)? In other words, will the participants' post-intervention assessment scores improve significantly from their initial pre-intervention assessment scores?

The following hypotheses were examined:

H_0: Use of EASe games for 28 days, twice a day will not significantly improve a child's visual attention skills, spatial organization skills or occupational performance at home as measured by SPM-Home Form, CTMT, or EASe game tracking scores, as analyzed using the Semiparametric Ratio Estimator (Weissman-Miller, 2005, 2008, 2009, 2010, 2011).

H_1: Use of EASe games for 28 days, twice a day will significantly improve a child's attention skills, spatial organization skills or occupational performance at home as measured by SPM-Home Form, CTMT, or EASe game tracking scores, as analyzed using the Semiparametric Ratio Estimator, SPRE (Weissman-Miller, 2005, 2008, 2009, 2010, 2011).

Participants

The study sample was considered a convenience sample because the child participants were selected from each facility's existing caseload. This sample was considered a purposive sample, as it targets a specific age range of children who exhibit sensory processing deficits. Thirty children with sensory processing deficits were expected to participate in this study. Twenty-one child participants were recruited from one clinic in metro Atlanta and 12 child participants from another clinic north of metro Atlanta. Child participants were selected from an existing caseload receiving occupational therapy from one of these two facilities and/or they had previously received occupational therapy at one point in time. Participants selected for analysis were randomly chosen who met the criteria for and had completed the trial for quantitative analysis using Semiparametric Ratio Estimator (SPRE).

Inclusion criteria. To be included in this study, child participants and their families were required to provide consent to participate in this study for twenty-eight consecutive days. Parents of the child participants were required to understand and speak English. Ages of children that were included were between eight to twelve years, 11 months old and the children were required to be able to follow age appropriate directions or commands as deemed by his/her treating therapist. Child participants were required to have associated visual, vestibular, or auditory sensory processing deficits associated with their diagnosis. Children were required to use recommended headphones. Children participants were required to have access to a Windows 7 or Windows XP computer compatible with EASe interactive games, as EASe interactive games are not compatible with other systems (Mueller, 2010).

Exclusion criteria. Non-English speaking parents of children who meet study criteria were excluded due to potential language barriers. Individuals who were unable to commit to twenty-eight consecutive days of playing interactive games were also excluded from this study. Children who were unable to follow age appropriate directions or commands were also excluded. Individuals without access to a Windows 7 or Windows XP computer were excluded.

Procedure

Prior to data collection, a Human Subjects Institutional Review Board application for the study was approved (Appendix C). Demographic data (Appendices D and E) for child participants and participating therapists and consent to participate in this study (Appendices F and G) were obtained upon the initial meeting and training session with child and family at each participating facility. Each child participant was assigned an identification number for use on all information, assessments, and data sheets collected to maintain participants confidentiality. One master list of identification numbers was generated by student researchers and kept by student researchers and participating facility managers. Therapists and student researchers at each occupational therapy clinic documented and reported as much demographic data as necessary to adequately describe the sample, along with information about the length of time the child has already been receiving occupational therapy services. The length of service, along with other factors that might influence the scores of a child, such as mood, hunger, or fatigue, will be considered covariate factors during data analysis, which are accounted for in analysis using the Semiparametric Ratio Estimator (Weissman-Miller, Shotwell, & Miller, 2011).

Pre-assessments, review of participant instructions and a demonstration of EASe games and music CDs were conducted with parents and child participants by occupational therapists at the participating facilities and the student researchers. Questions from parents and child participants were answered and parent training packets (Appendix H) were provided, consisting of game instructions, the name of each facility's manager and the researchers' contact information.

Occupational therapists and occupational therapy graduate student researchers evaluated the child participants during pre-assessment and post-assessment using the Sensory Processing Measure (SPM)-Home Form (Parham & Ecker, 2007) and the Comprehensive Trail Making Test (CTMT) (Pro-Ed, 2011). Assessments were fully administered by the child's occupational therapist or occupational therapist student researcher, or partially administered by both. The occupational therapist supervised all testing performed by the graduate student researchers to ensure adherence for all standardized procedures. Clinical observations were documented during the pre-assessments and post-assessments (Appendix I). Clinical Intake Data Sheets (Appendix D) for each child participant included information regarding prior or current therapy in terms of type, length of time, experience with visual, auditory, or vestibular programs and other pertinent data.

The EASe game protocol was verbally explained to each child participant by the occupational therapist or graduate student researchers. Child participants and parents were trained in the use of EASe music CDs and interactive games by one of the four student researchers or an occupational therapist. Training packets were issued for child participant and parent reference, including daily log sheets for parent tracking of the type of game the child played or music to which the child listened and time-frame for play or listening.

An occupational therapy graduate student researcher made follow-up calls to their assigned families every three days beginning on the third day of the twenty-eight day intervention. Within one week of the end of the intervention period, a semi-structured interview (Appendix J) was conducted by telephone or in person with parents and child participants to gain further insight into the overall experience and family perspective of the child participants' use of the EASe games during the study trial.

Data Collection Strategies

Testing with Sensory Processing Measure-Home and Comprehensive Trail Making Test were conducted in a clinic-based setting. Parents or caregivers completed the SPM-Home Form independently or with occupational therapist or researcher assistance with reading of or explanation of the questions posed in the assessment. Therapist or student researchers documented any notes about how the questionnaire was administered.

EASe games or music CDs were played by the child participant in their home setting unless otherwise indicated. Child participants were permitted to use games and CDs in other settings, such as at each participating therapy clinic if necessary, so long as all recommended study protocol parameters for use of EASe products were met. These parameters included utilizing recommended headphones (ATH-FC700A; Audio-Technica, 2011) and a computer mouse. The two EASe games, Off Road and Treasure Hunt, have been created with a system that tracks an individual's game usage, time spent playing the game, the amount of time it takes to complete each game level, and individual total scores. To ensure reliability and consistent use of the EASe games or music CDs, follow-up calls and/or emails every three days were made by the graduate student researchers to their respectively assigned child participants and families (Appendix H).

EASe game play was scheduled to be completed over 28 days, grouped into 2 cycles of 14 days each (see *Table 1*). During each cycle, each child played the specified EASe interactive game twice a day for thirty minutes per session, spaced at least 3 hours apart. For group A,

Table 1
Example Schedule of EASe Intervention, Based on Monday Intervention Start Date

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	Day 1 Pre-Intervention Testing 2 sessions: ETS: FH PDC: OF	**Day 2** 2 sessions: ETS: FH PDC: OF	**Day 3** 2 sessions: ETS: FH PDC: OF	**Day 4** 2 sessions: ETS: FH PDC: OF	**Day 5** 2 sessions: ETS: FH PDC: OF	**Day 6** 2 sessions: ETS: FH PDC: OF
Day 7 2 sessions: ETS: FH PDC: OF	**Day 8** 2 sessions: ETS: FH PDC: OF	**Day 9** 2 sessions: ETS: FH PDC: OF	**Day 10** 2 sessions: ETS: FH PDC: OF	**Day 11** 2 sessions: ETS: FH PDC: OF	**Day 12** 2 sessions: ETS: FH PDC: OF	**Day 13** 2 sessions: ETS: FH PDC: OF
Day 14 2 sessions: ETS: FH PDC: OF	**Day 15** 2 sessions: ETS: OF PDC: FH	**Day 16** 2 sessions: ETS: OF PDC: FH	**Day 17** 2 sessions: ETS: OF PDC: FH	**Day 18** 2 sessions: ETS: OF PDC: FH	**Day 19** 2 sessions: ETS: OF PDC: FH	**Day 20** 2 sessions: ETS: OF PDC: FH
Day 21 2 sessions: ETS: OF PDC: FH	**Day 22** 2 sessions: ETS: OF PDC: FH	**Day 23** 2 sessions: ETS: OF PDC: FH	**Day 24** 2 sessions: ETS: OF PDC: FH	**Day 25** 2 sessions: ETS: OF PDC: FH	**Day 26** 2 sessions: ETS: OF PDC: FH	**Day 27** 2 sessions: ETS: OF PDC: FH
Day 28 2 sessions: ETS: OF PDC: FH	**Post-Intervention Testing**	**Post-Intervention Testing**	**Post-Intervention Testing**			

Note. ETS = clinic north; PDC = clinic metro; FH = Fun House Treasure Hunt; OF = Off Road Treasure Hunt.

participants from one clinic known as ETS, Cycle 1 consisted of playing the Fun House Treasure Hunt game (FH), while Cycle 2 consisted of playing the Off Road Treasure Hunt game (OF) on the computer while wearing recommended headphones and listening to music generated by game. For group B, participants from the other clinic known as PDC, Cycle 1 consisted of playing the Off Road Treasure Hunt game, while Cycle 2 consisted of playing the Fun House Treasure Hunt game. Day 1 of intervention began for each child on the day as pre-intervention testing. If at any point in time a child is unable or chose not to participate in the specified game for that day, he/she was given the option to listen to his/her choice of EASe audio CD for the same set amount of time. In this study the EASe music CDs have were assigned names for client EASe of recognition; they included CD 1-"shaping clouds" and CD 2-"in the sky".

Post-intervention testing using the SPM-Home Form and the CTMT were completed following Day 28 of EASe intervention by the occupational therapy students, or the child's occupational therapist. To gain child and parent feedback on the overall effect and usefulness of the EASe games and music CDs a semi-structured interview was conducted.

Measures

For the purpose of this study The Sensory Processing Measure (SPM)-Home Form and the Comprehensive Trail Making Test were selected as pre-assessments and post-assessments. The Sensory Processing Measure (SPM)-Home Form was originally designed to be used by occupational therapists, psychologists, teachers, social workers, counselors, physical therapists, speech-language pathologists, or nurses to obtain a clearer picture of children's sensory functional performance at home, school, or in the community (Parham & Ecker, 2007). The Sensory Processing Measure (SPM)-Home Form is a standardized self-report measure that has 75 items and gives eight different standard scores: Social Participation, Vision, Hearing, Touch, Proprioception, Vestibular, Planning and Praxis, and Total Sensory Systems. This self-report measure was completed by the parent or caregiver of participating children.

The instrument aids the therapist in identifying the sensory systems and types of processing problems involved in social participation, vision, hearing, touch, body awareness, vestibular, planning and praxis, and total sensory systems. The Sensory Processing Measure (SPM) Home From form typically takes 15-20 minutes to complete and is scored on a 4-point Likert scale (never, seldom, sometimes, or always). Results indicate the higher the raw score, the greater the dysfunction in social, visual skills, hearing, touch, proprioception, vestibular function, planning and praxis, and total sensory systems (Parham & Ecker, 2007).

The Comprehensive Trail Making Test (CTMT) is a standardized test consisting of five visual searches and sequencing tasks that are heavily influenced by attention, concentration, resistance to distraction, and cognitive flexibility. The fundamental aspect of trail-making is to connect a series of stimuli (numbers, expressed as numerals or in word form, and letters) in a specified order as fast as possible. The score derived for each trail is the number of seconds required to finish the trail (Pro-Ed, 2011). The five trails become more difficult as they progress, for example:

- “The examinee draws a line to connect the numbers 1 through 25 in order. Each numeral is contained in a plain circle.
- The examinee draws a line to connect the numbers 1 through 25 in order. Each numeral is contained in a plain circle. Twenty-nine empty distractor circles appear on the same page.
- The examinee draws a line to connect in the numbers 1 through 25 in order. Each is contained in a plain circle. Thirteen empty distractor circles and 19 distractor circles containing irrelevant line drawings appear on the same page.

- The examinee draws a line to connect the numbers 1 through 20 in order. Eleven of the numbers are presented as Arabic numerals, (e.g., 1, 7); nine numbers are spelled out (e.g., Ten, Four).
- The examinee draws a line to connect in *alternating* sequence the numbers 1 through 13 and the letters A through L. The examinee begins with 1 and then draws a line to A, then proceeds to 2, then B, and so on until all the numbers and letters are connected. Fifteen empty distractor circles appear on the same page." (Pro-Ed, 2011).

The composite score is obtained by pooling the *T*-scores from the individual trails. The five trails are similar but also are different in some significant way. This easily administered set of tasks is reported to be remarkably sensitive to neuropsychological deficits of many types.

The CTMT was designed to resolve issues of inadequate norming and scoring inconsistencies found in Partington & Leiter's (1949) original *Trail Making Test, Parts A and B* (TMT). Norms set for the CTMT are included for participants between the ages of 8 years, 0 months and 74 years, 11 months. Scoring is calculated based on total length of time for successful completion of each trail and is measured in seconds for each trial assessed. Any errors result in starting over and longer completion times. Administering the CTMT is timed and takes from 5 to 12 minutes and scoring typically takes less than 10 minutes (Reynolds, 2002). In this study, the child will complete all five trails. Results of the Comprehensive Trail Making Test (CTMT) indicate the higher the score, the greater the dysfunction in attention, psychomotor speed, and mental flexibility (Reynolds, 2002).

Reliability and Validity of SPM and CTMT

The Sensory Processing Measure (SPM) Home Form was standardized on a demographically representative sample of 1,051 typically developing children in kindergarten through sixth grade. Scores for the home form fall into three interpretive ranges: Typical, Some Problem and Definite Dysfunction (Parham & Ecker, 2009). For the Home form, scaled scores, internal consistency estimates ranged from .77 to .95 (median = .85), and test-retest reliability estimates ranged from .94 to .98 (median = .97).

The Sensory Processing Measure also consists of Main Classroom Form consists of 62 items and is completed by the child's primary teacher. Additionally, the SPM-School Environment Form has 10 to 15 items per environment, which is completed by other school professionals who interact with the child. The child's performance is assessed within six areas of school environment such as the cafeteria, the Art classroom, Physical Education, Music Class, Recess/Playground, and School Bus. Scores for the Main Classroom and Home form are identical, but each item addresses a specific environment. (Parham, Ecker, Kuhaneck, Henry, and Glennon, 2009).

The Home and Main Classroom forms each provide eight standard scores in areas of social participation, hearing, vision, touch, proprioception, vestibular function, praxis, and total sensory systems. A standardization sample was used to develop scores and establish cut-off criteria for the School Environments Form. Additionally a separate sample of 345 children receiving occupational therapy intervention was conducted to validate that the Sensory Processing Measure (SPM) scales can distinguish typically developing children from those with clinical disorders (Parham & Ecker, 2009).

The Comprehensive Trail Making Test is standardized from a nationwide sample of 1,664 people whose demographic characteristics match the United States 2000 census data (Pro-Ed, 2011). Standardized scoring is provided in the form of normalized T-scores for each trail and composite scoring. Each normalized T-score within the sample had a mean of 50 and a standard deviation of 10, with their accompanying percentile rankings (Reynolds, 2002). Internal consistency for the Comprehensive Trail Making Test (CTMT) cannot be established since this test measures speed; however, correlations between each trial and composite of the additional four trials were used as a reliability index reflecting sampling error (Strauss, Sherman, & Spreen, 2006).

Reliability of scores for each individual trail were acceptable and the composite score has a reliability coefficient of .90 or higher at all ages (Pro-Ed, 2011). A Comprehensive Trail Making Composite Index is derived from overall performance across each trail. Scores generated from the first three trails measure simple sequencing with scores generated from the last two trails measure complex sequencing. However, single scores can be calculated for some parts of the Comprehensive Trail Making Test (CTMT) (Strauss, Sherman, & Spreen, 2006).

Data Analysis

Preliminary results were analyzed based on within-subjects comparisons of participant pre-intervention and post-intervention assessment scores using the Sensory Processing Measure (SPM) Home Form and the Comprehensive Trail Making Test (CTMT). However, due to several factors, such as inconsistent game play, family schedules, or the child participants' response to games, the researchers utilized a single-subject and small group design using the Semiparametric Ratio Estimator (SPRE) model. This was used to determine the number of treatment sessions required to predict a change point and at what point the child participant stabilizes in their performance using either Fun House or Off Road games. The formula used for calculations to predict the child participant maximum benefit of the game is $\hat{\theta}_t = \left(\frac{1 - e^{-\left(\frac{t_{i+1}}{\tau}\right)^{k}}}{1 - e^{-\left(\frac{t_1}{\tau}\right)^{k}}} \right) \cdot \theta_1$ (Weissman-Miller, Shotwell, and Miller, 2011). The numerical data collected from this model was used to determine if a significant change occurred in child participant scores after intervention using the EASe program interactive games and/or audio CDs. The simplified formula used for this calculation is $\hat{\theta}_t = R \cdot \theta_1$ (Weissman-Miller, Shotwell, and Miller, 2011).

Clinical observations were also gathered from the occupational therapy clinicians, consisting of any behavioral changes in child participants scheduled therapy intervention for descriptive statistics. Data from observational reports were subsequently recorded for analysis by the therapist or student researchers. The student researchers' analyses were discussed with each child's occupational therapist to ensure accurate representation of the child participant during the twenty-eight day intervention.

Upon completion of the EASe program intervention, daily data logs consisting of information regarding daily game sessions, name of game or music CD, and time spent playing the games were collected for analysis of data to provide descriptive contextual and behavior information. The two EASe games, Off Road and Fun House Treasure Hunt, chosen as the intervention in this study have been created with a system that tracks an individual's game usage, time spent playing the game, the amount of time it takes to complete each game level, and individual total scores. Higher scores indicate improved performance therefore implying better sensory integration.

The raw data from tracking logs automatically generated by the EASe Off Road and Fun House Treasure Hunt game software were analyzed using R Excel, R Commander, and the Semiparametric Ratio Estimator (SPRE). The Semiparametric Ratio Estimator (SPRE) model allows studies to be conducted on single subject or smaller groups of participants while maintaining internal and external validity to predict future outcomes of performance using initial data from treatment interventions (Weissman-Miller, Shotwell, & Miller, 2011). Internal validity is demonstrated by a "least squares method resulting in an unbiased estimate and external validity is given to a participant or small group when the *p*-value for the F statistic at the change point is lower than or equal to 0.05. The statistical population parameter Θ at the change point indicates outcome parameters over time for that single subject, or population mean for a smaller group" (Weissman-Miller, Shotwell, & Miller, 2011, p. 7).

In this study, it was anticipated that 56 data points per child would be taken from the raw tracking data (2 sessions for ½ hour x 28 days) for data analysis. The minimum number of sessions required for use of interactive games was 9 per child for inclusion in SPRE analysis. In other words, in order to utilize SPRE, the researchers needed to gather 9 data points from each child participant's game raw tracking data. A total of five participants with six data sets (three who engaged in Fun House game and three who engaged in Off Road game) who met the criteria for the SPRE analysis were randomly chosen in this study for analysis.

For each participant an EASe Proficiency Score was calculated in Excel based on points generated by the data logs for each playing session with respect to the amount of time spent playing each game session. All scores associated with their respective treatment days were statistically ordered in sequence necessary for therapy outcomes. Each participant's SPM pre-assessment total score was divided by the EASe Proficiency Score to normalize the data for each child participants which were also ordered from descending to ascending order. The square root was taken of scores divided by SPM pre-assessment scores. The log of each day was calculated in preparation for using R commander. Using R Commander the R^2, F statistic and the *p*-value was calculated from the Analysis of Variance (ANOVA) to predict a change point in the SPRE model by using squared scores and log days. The F statistic defines a statistical change point, which is the data point at which the character of the regression changes from linear to curve which allows for prediction of future outcome points (Weissman-Miller, Shotwell, & Miller, 2011). A regression analysis was conducted using Semi-Parametric Ratio Estimator (SPRE) to predict outcomes and possible trends among the child participants. The findings from the study will serve to provide evidence regarding the length of time where participants in this study attained the maximal potential benefit from playing the EASe program.

Developed by Dr. Deborah Weissman-Miller (2005, 2008, 2009, 2010, 2011), SPRE is a form of single-subject design that has both internal and external validity. According to Weissman-Miller (personal communication, July 20, 2011), SPRE has internal validity because it uses Ordinary Least Squares (OLS) Regression in order to determine the change point, where the change point is represented by the highest or lowest F statistic. If residual errors from the data at the change point have a normal spread on a graph, then the outcome measures at that change point are valid and become a population parameter. This means that all predicted outcomes from the change point using the SPRE ratio belong to that particular participant. While the population parameter at the change point ensures external validity, the definition of predicted outcomes for a single subject can only belong to that participant.

Semi-Parametric Ratio Estimator (SPRE) measures the total response of the child on any particular day through the game scores thus capturing the multiplicative interactive effects such as demeanor, fatigue, or illness. SPRE was created to produce viable statistical analyses of observational and clinical data using small sample sizes while still maintaining statistical validity. SPRE derives a single outcome then takes the entire persons' response to the intervention into account during the treatment session; meaning it has the ability to account for external and internal factors thus producing a holistic, occupation-based statistic for analysis (Weissman-Miller, 2011).

Researcher Bias and Assumptions

Potential biases of the researchers conducting this study include the desire for this study to be successful. Control for this potential bias was addressed through the use of standardized assessments (Sensory Processing Measure (SPM) Home Form and Comprehensive Trail Making Test) along with the Semi-parametric Ratio Estimator to analyze results. Potential bias may also be that the student researchers' thesis advisor owns one of the two therapy facilities used in this study to obtain the expected convenience sample. The student researchers plan to control for this bias through documentation and discussion of all therapy interventions related to this study with their thesis committee.

Additionally, one of the two occupational therapists who will administer the assessments will provide recommendations for study participants from clients at her facility. She has previously used the EASe program as intervention with some of her clients, and has personal interest in the success and promotion of the program. Student researchers plan to address this potential bias by observing, recording, discussing, and monitoring throughout the assessment and intervention process. The thesis advisor, participating clinics, and biostatistician were also blinded during the analysis of this study to assist with controlling bias.

An additional assumption is that all occupational therapists and student researchers involved in administering assessments and training of EASe products were competent in administration and interpretation of the assessments and use of EASe products. To address this assumption, the student researchers and occupational therapists met and conducted ongoing discussions regarding the administration, scoring, and interpretation of the assessments on a consistent basis. Additionally, they reviewed and discussed the study protocol regarding use of EASe products games and CDs.

The researchers also assumed that raw data produced automatically by the EASe Off Road and EASe Fun House Treasure Hunt software would provide valid and significant tracking data. Although this has been confirmed by creator of EASe games, Bill Mueller, in personal conversation, the researchers assumed that no technical errors or complications in use of the EASe programs that would impact results of the study. This bias was addressed by providing families with training on the games, including demonstration in using the games, assessing game logs, and consistent, frequent communication with parent(s) of child participants throughout the study.

Timeline and Budget

Potential child participants were selected from an existing therapy caseload from the two participating therapy clinics. Child participants were contacted, tested and received therapeutic intervention as part of their usual occupational therapy sessions between September and October 2011. Data analysis was conducted during October and December 2011 as part of each child participant outcome measures, along with all other aspects involved in completion of the study. These included a compilation of results and discussion of study findings for the final document, as well as development of a graduate poster in partial fulfillment of requirements for a Masters degree in occupational therapy. The poster will be submitted for acceptance into the graduate poster sessions at national or state occupational therapy professional conferences. The researchers' budget includes funds for travel, printing research materials, such as articles, chapters of the study for proofing, data, parent packages, and binding of the final thesis.

Summary

The purpose of the current study was to explore the effect of Electronic Auditory Stimulation effect (EASe) games with 8-12 year old children who exhibit audio-visual-vestibular processing deficits. This study was the first pilot study to explore the efficacy of EASe interactive games or audio CDs with children who use the games at home or in their respective occupational therapy sessions. Information and knowledge significant to the study was gathered from the existing literature on the topics of the study and interviews with the designer of the EASe products, William P. Mueller.

After consent, testing with Sensory Processing Measure (SPM) Home Form and the Comprehensive Trail Making Test (CTMT), and training on the use of EASe games, the child participants used the EASe products for twenty-eight days. This pilot study was set up as a two-arm trial, where participants played one game for 14 days and then reversed and played the second game for 14 days. Tracking of game playing raw data provided by the interactive games was analyzed for five child participants, one participant who played both games with none or more data points using Excel, R Commander, and the Semiparametric Ratio Estimator (SPRE).

CHAPTER 4

RESULTS

This pilot study was conducted to examine the efficacy of EASe interactive games, Fun House Treasure Hunt and Off Road Treasure Hunt, with children aged 8-12 years. The researchers were able to predict the number of days of EASe game-play necessary for individual participants to demonstrate tolerance of the sensory input provided by each game in order to achieve and sustain maximum benefit from game play. In this study, we hypothesized that the EASe games and music CD's would improve the child participant's visual attention, visuospatial tracking, and task sequencing, as measured by lower scores on the Comprehensive Trail Making Test (CTMT; Reynolds, 2002), and social participation, vision, hearing, touch, body awareness, vestibular function, and planning, as measured by lower scores on the Sensory Processing Measure-Home Form (SPM-Home; Parham & Ecker, 2009).

The original study protocol called for each participant to play a total of two game cycles, one cycle of Off- Road Treasure Hunt and one cycle of Fun House Treasure Hunt during the 28 day period, as shown in Table 1 in chapter 3 of this document. In Fun House Treasure Hunt, the child drives a buggy through six different play rooms as they collect treasures or simply explores the Fun House. The Off Road Treasure Hunt is a driving game which takes place outdoors in a desert setting where the vehicle travels over hilly terrain in search of targets. For each game, the player listens to EASe music via specialized headphones as they are presented with visual and vestibular challenges.

Participants

Due to various conflicts, such as missing data or missed sessions due to family schedules, resulting in breach of study protocol, some participants' game logs were disqualified. At the end of the data collection period, researchers randomly chose six participants who had consistently followed the study protocol from which to analyze game scores and only five participants' data sets met the study criteria for analysis using the Semiparametric Ratio Estimator (SPRE).

Demographics for the six participants included in the data analysis are listed below in *Table 2*. Three datasets were selected from participants who began the first 14-day cycle of EASe game play using Fun House Treasure Hunt, and four datasets were selected from those who began the first cycle using Off Road Treasure Hunt. Child participant 1Q game logs were selected for analysis from both Off Road Treasure Hunt (Cycle 1) and from Fun House Treasure Hunt (Cycle 2) for analysis as they contained an adequate number of sessions (9 or more) to qualify for analysis. All datasets, with the exception of that from participant 1A, were analyzed to completion using the Semiparametric Ratio Estimator (SPRE) to predict future outcomes.

Table 2
Participant Demographics

Participant ID	Gender	Age	School Type	Glasses	Diagnosis
1A*	M	12	Home	Yes	Autism, vestibular dysfunction, dyspraxia, muscular weakness
1I	M	12	Public	Yes	Autism
1M	F	11	Public	No	Asperger's, vestibular dysfunction, dyspraxia, muscular weakness
1Q**	M	8	Public	No	Motor Dysgraphia, vestibular dysfunction, dyspraxia
1U	M	11	Home	No	Autism

1Y	M	12	Home	Yes	PDD-NOS

Note. *IA Not used due to inconsistent data. **Datasets from both Off Road and Fun House were analyzed for participant 1Q.*

Several aspects of the original protocol changed during the course of this study. A number of parents expressed that there was not adequate time in their child's schedule during the school year to participate in their various after school activities, complete their homework, and participate in this study. These families decided not to take part in the study and several remaining parents were hesitant to commit to the study because of the same concerns. For this reason, the protocol was adjusted to help make it possible for some families to participate. For example, it was decided that on busy days it would be permissible for children to dedicate one half hour session of game playing rather than the two sessions originally called for in the protocol. For study participation it was also decided that the children would be allowed to listen to EASe music CDs on days when their busy schedules conflicted with game playing or if participants were unable to tolerate game playing due to sensory sensitivity throughout the duration of the study.

Additional amendments that were made to the study to accommodate families' busy schedules at the start of the new school year included scheduling of pretesting and post-testing dates. The research protocol called for all participants to complete pretesting on the same date so they would be provided the same information and to control for consistency. One of the participating occupational therapists suggested that parents at her site would unlikely attend a group information session on a school night before the start of the study. To accommodate for this potential conflict, some of the participants' pretesting sessions were scheduled on days where they were already scheduled for a therapy session. In order to ensure the post-testing date fell on the same day of the week as these participants' therapy sessions, the length of the study was shortened from thirty days to twenty eight days, resulting in a decrease of game play days from fifteen days to fourteen days of game play.

At the other clinic study site, the participating occupational therapist was able to come in on one designated Saturday and confirmed that the participating children's families would also come in for training and testing on that Saturday. Conducting pretesting on a Saturday was a better choice at this clinic because it allowed extra time for children to complete the testing if necessary as well as receive training in game play. This additional training time was not needed at the other clinic because the head occupational therapist does not conduct therapy sessions with the children; she manages the staff. As such she was able to test the children within their therapy time.

The original protocol stated that graduate students would check in with participants' parents every three days to monitor their game playing and to answer parents' questions and/or document their observations. At first, three parents did not answer calls due to changed contact numbers. The graduate students were initially unaware that the phone numbers had changed because they were able to leave voicemails. Even though the researchers were unable to reach these parents, they had been provided the contact numbers for the researchers and occupational therapists at each clinic involved in the study. Additionally, some families often did not answer the researchers' monitoring calls, particularly toward the end of the study. The graduate student researchers left messages in these cases and followed up with emails asking if the families were experiencing any technical issues, concerns regarding the games, or if they notable observations to report.

A concern of the researchers arose after some changes were made in regard to study participants near the beginning of the pretesting period. The age span of the children participating was increased by one year to accommodate additional children. Though datasets of these particular children would not be included in the data analyses, the researchers decided that these children should still take part in the study trial and post-testing so that their data might be referenced in future studies.

Another concern during this study was potential bias. One of the participating occupational therapists (OTs) had a sustained business relationship with the game developer for several years. Though they spoke infrequently during this study trial, their conversations were regarding the EASe games. As such, it is likely that the OT wanted the study to show positive results. One way the researchers controlled for this potential bias was through the use of participant ID numbers, so that all scoring was performed blindly by the OTs and researchers.

Testing Outcomes/Measures

The researchers examined the pretesting and post-testing scores for both the Comprehensive Trail Making Test (CTMT) and the Sensory Processing Measure- Home version (SPM-Home). The CTMT scoring involves a total composite score of 5 subtest scores, each increasing in complexity and amount of time necessary to complete each trail. The CTMT provides a qualitative interpretation of performance using descriptions, including: Below Average, Average, High Average, Superior, Very Superior. The SPM- Home measures the following areas: Social, Visual, Hearing, Touch, Taste and Smell, Body Awareness, Balance and Motion, and Planning and Awareness. Scores are interpreted using qualitative measures, including: Typical, Some Problems, and Definite Dysfunction. The Comprehensive Trail making Test (CTMT) and the Sensory Processing Measure Home Form pre and post test scores were not compared in the data analysis of this study as originally planned due to no significant change in child participant categorization results. The interpretations for each participant's scores on these standardized assessments are shown in *Table 3*.

Table 3
Pre-Assessment and Post-Assessment Scores with Parent Log Comments

Participant	Type of Measurement	SPM - Pre	SPM - Post	CTMT - Pre	CTMT - Post
1A	Composite Score	111	88	43	40
	Interpretive Range	Some probs	Some probs	Average	Below Average
	Parent Log Comments	Quirks decreased. "Child regretted playing" the game.			
1I	Composite Score	94	80	32	40
	Interpretive Range	Some probs	Some probs	Below Average	Below Average
	Parent Log Comments	Child "focused the whole game and a huge improvement was noticed with handwriting!"			
1M	Composite Score	78	77	74	84
	Interpretive Range	Typical	Typical	Very Superior	Very Superior
	Parent Log Comments	Child lost interest after 1 week of play.			
1Q	Composite Score	77	70	55	61
	Interpretive Range	Typical	Typical	Average	High Average
	Parent Log Comments	Child was "amped up".			
1U	Composite Score	92	88	39	41
	Interpretive Range	Some probs	Def. Dysf.	Below Average	Below Average
	Parent Log Comments	Child would sometimes yell, growl and bark at his family members. Mother noted that during the period of game play it was hard for this child to verbalize his feelings. On the final day of play, the child stated "I am so glad to be done with this game!"			
1Y	Composite Score	108	90	52	48
	Interpretive Range	Some probs	Some probs	Average	Average
	Parent Log Comments	Child complained about wearing headphones and continued to play without them part way through. Childs "legs felt shaky", behavior improved, and was more compliant post-game play. Parent stated the game was easy to use at home.			

Note: Interp. Range = Interpretive Range; Some probs = Some problems; Def. dysf. = Definite dysfunction

Participant 1A. Participant 1A is a 12 year old male with the diagnoses of vestibular dysfunction, dyspraxia and muscular weakness. His CTMT Composite Index Description Score was “Average” pre and “Below Average” post intervention. On the SPM-Home Form, his interpreted scores demonstrate increases in the areas of Social Participation and Touch, rising one level in each area. His pretest score for Social Participation was “Some Problems” and his post test score in this area was “Typical.” His pretest score for Touch, “Definite Dysfunction,” rose to “Some Problems” at post-test. The remaining categories covered on the SPM remained at the same level on the pretest as on the post-test. These scores were interpreted as: “Some Problems” for Vision, Hearing, Body Awareness, and Planning and Ideas, and “Typical” in the area of Balance. Overall, participant 1A’s SPM total score of “Some Problems” remained the same from the pretest to the post-test. Participant 1A’s mother noted on the SPM post test comments section on behavior/functioning that the “quirks he has have diminished over the last month.” His father stated that the child had regretted participating in the study.

The following is an example of how this child participant played the Off Road game. He played this game for the full hour each day of play during Cycle 1 except for one day when he listened to EASe music for an hour instead of playing the game. Within the Off Road game, the player can choose from two settings: Open Savannah, which is for beginning players and Red Rock Range, for more advanced players. This player switched from the easy to hard game option after 15 minutes of play time during the first session of play on Day 1. That evening this child went back to the easier level. The two settings are not scored the same and the participant initially scored better when playing the less difficult option. Once he mastered the harder setting he was able to attain higher scores.

On the parent log for the first day it was noted that Participant 1A did not like the “clanging” sound from the music. On Day 2, the child chose the more difficult setting. During the first session of game play time on Day 2, he chose to take off the headphones for part of the time as the acoustics were irritating to his auditory system. Lowering the volume of the sound or taking the headphones off was recommended for children who were bothered by the music based on the severity of their sensory sensitivities. As the users assimilated to the music, they were told to slowly increase wearing time and/or volume as appropriate. That afternoon's second session of play "felt longer" to him than it had earlier in the day, according to his parents' log. On the afternoon of Day 3, it was noted that the "clanging in the music" continued to irritate this participant. During the second session the evening of Day 3, however, the sound from the game did not bother his auditory system. Though the music did not bother him during this second session, it again was reported that the second half hour of play "felt longer" to him than the earlier session had.

A parent noted that Day 4 of play was the first time Participant 1A used the mouse as a control rather than the keyboard. Beginning the second session of Day 4, this participant played "Red Rock Range" exclusively for the remainder of the study. It is noteworthy that this participant played a full hour Day 5, but only for a half an hour Days 6, 7, 8, and fifteen minutes on Day 9. On Day 10 participant 1A played again for a total of an hour, but substituted the game with music on Day 11. He played two full sessions on Days 12 and 13. On Day 14 it was noted that participant 1A's mother was not home to direct him to play the game and that he opted to listen to the EASe music instead of playing the game. The final day of play, Day 15, his mother was home to enforce game play and he played for the full hour. In the post interview, the participant's father shared that his child had regretted participating in the study. His mother was pleased that she had noticed a "decrease in his quirks" after several game sessions and that these had not returned.

Participant 1A's game logs for EASe Off Road Treasure Hunt were analyzed using SPRE. For each participant, an EASe Proficiency Score was calculated in Excel based on points generated by the data logs with respect to time spent playing each game session. All scores associated with 1A's respective treatment days were statistically ordered in sequence necessary for therapy outcomes. Participant 1A's game logs were analyzed to obtain a change point from which to predict future response to Off Road game play. In SPRE analysis, for future prediction of outcomes, there is a need for linearity of data. Therefore, participant1A's scores were normalized by dividing by 1A's total score on the Sensory Processing Measure – Home Form from the pre-intervention assessment in order to use the Semiparametric Ratio Estimator (SPRE) to make generalizations. From there, the data was linearized by taking the square root of the ratio. The day value was also linearized by taking the Log of each Day for this same linearity reason. Once linearized, the SPRE was used to perform a linear regression to find the change point from which to predict future outcomes. At this point, participant 1A's dataset was not analyzed further for predictions, as the score generated for R^2 was too low (.183), indicating very little correlation between their scores and treatment day (see *Table 4*).

As stated in Chapter 3, in order to make predictions, correlations of scores and treatment days need to be fairly high (> .500) in order to utilize SPRE for analysis (Weissman-Miller, Shotwell, and Miller, 2011). Participant IA data was so erratic with respect to time that we could not proceed with analysis using SPRE, limiting us to information provided in the parent data logs explained above. The data from this child participant was fractured. Criteria for SPRE analysis requires linearity, therefore researchers were unable to use this data for further SPRE analysis.

Table 4

Participant 1A Off Road Scores

SqRtScore	LogDay	Day	R^2	Fstat	*p*-value
1.7	0.301	2*	0.525	12.170*	0.005*
1.63	0	1	0.475	9.037	0.013
1.38	1	10	0.183	0.898	0.397
1.36	1.079	12	0.134	0.456	0.544
1.4	0.903	8	0.014	0.098	0.763
1.39	1.176	15	0.014	0.085	0.781
1.39	0.477	3	0.011	0.058	0.820
1.36	0.845	7	0.017	0.034	0.871
1.33	1.114	13	0.032	0.033	0.886
1.41	0.954	9	0.001	0.010	0.922
1.41	0.699	5	0.000	0.001	0.975

Note. Scores are ordered by highest to lowest F-statistic in order to locate the change point. *Day 2 indicates the highest F-statistic and lowest *p*-value. However, use of only 2 days of data is inadequate for use in predicting future outcomes. Therefore we look to the next highest adequate F-statistic, in this case at Day 10. The R^2 value for 1A at Day 10 is .183, and participant 1A's data overall is irregular, erratic, and non-linear, and therefore is unusable for predictions of future outcomes using the SPRE.

Participant 1I. Participant 1I is a 12 year old male with the diagnosis of Autism Spectrum Disorder. This participant's CTMT Composite Index Description Score was "Below Average" pre-intervention as it was post-intervention. On the SPM-Home Form, his interpreted scores show an improvement in the area of Planning and Ideas, rising one level from "Some Problems" to "Typical." The remaining categories covered on the SPM remained the same pretest and post-test. The score of "Typical" was in the categories of Social Participation, Hearing, Touch, Body Awareness, and Planning pre-intervention and post-intervention. The score of "Some Problems" was indicated in the areas of Vision and Balance. Overall, the SPM total score of "Some Problems" remained the same pretest and post-test.

Participant 1I's Off Road Treasure Hunt game logs were analyzed using SPRE (see *Figure 1*) and cross examined with parent communications. Participant1I's scores were normalized and linearized by using the same SPRE method. Once linearized, the SPRE was used to perform a linear regression to find the change point from which to predict future outcomes. A change point was identified at Day 13, with an R^2 value of 1.03, indicating a high correlation between 1I's scores and treatment day (see Appendix K for R^2 calculations).

Outcome predictions were then calculated with respect to his change point. *Figure 1* displays Participant 1I's scores plotted with respect to time, with additional future outcomes plotted after the change point (circled). The red broken line from the first outcome to the change point represents the approximation to the ordinary least squares line, which was used in a backwards stepwise regression to determine the change point from Participant 1I's normalized, linearized and ordered data. As this line was used during analysis only for determination of the change point and not as an outcome data, it is drawn as a broken line. This line is an approximation to the ordinary least squares line used in the linear regression.

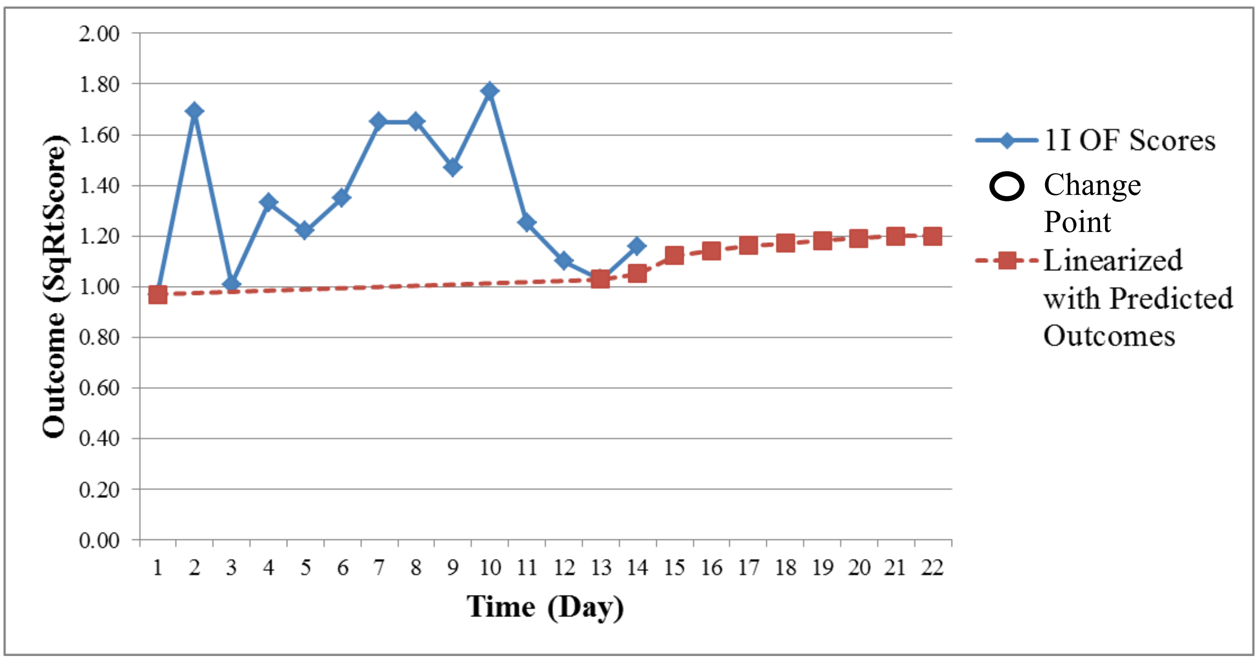

Figure 1. Participant 1I Off Road Graph with Predicted Outcomes

Participant 1I is a 12 year old male with the diagnoses of Autism Spectrum Disorder. CTMT Composite Index Score=Below Average (pre and post-intervention), SPM-Home From=Some Problems (pre and post-intervention), Change point=Day13, Maximum Benefit=Day 22, Percent difference in predicted outcome versus actual score at Day 14=10.48%

Participant IA's predicted outcomes were calculated through to the day in which the calculated ratio of change plateau at 1.00, indicating no further benefit from the use of the game. Participant 1I reached this maximum benefit of play at Day 22.

The following descriptive data was taken from 1I's parent daily logs. For the first session of Day 1 it was noted that he got very tired and was not able to stay focused. The second half hour session it was noted that he was more focused during game play. On Day 2 from parent log comments the participant played the first session without exhibiting any out of the ordinary behaviors. The second half hour session of that day he was "eager to be done." On Day 3 from parent log it is recorded that one half hour session was played in the afternoon with "nothing unusual" noted by the parent. The first session on Day 4 parent log notes that it was difficult; he was very distracted while playing and "only lasted 15 minutes and five minutes of music." The second session of Day 4 was much different. The child was able to stay "focused the whole game and a huge improvement was noticed with handwriting!"

Two half hour sessions were played on the fifth day with no notable parental observations. The first session of Day 6 it was noted that the participant was "focused on the game but complained of being bored." During the second session of Day 6 some of the participant's focus turned from tagging points to trying to find "glitches" in the game per observations noted on parent game log. Participant began to look for flaws within the interactive game. Parent logs from days 7 and 8 revealed no new or out of the ordinary behaviors from this participant. The morning of Day 9 parent game log reported that the day was also typical but the participant fell asleep during the second game play session. On Days 10 through 14 parent game logs report the participant was on a vacation and played the game on a portable computer using the keyboard rather than the mouse. It was noted that the player had a difficult time staying focused on the game during this period. Music was substituted for part of the first game session on Day 12, all of the second thirty minute period on Day 13 and one thirty minute game session was played on Day 14.

Participant 1M. Participant 1M is an 11 year old female with the diagnoses of Asperger's Syndrome and muscular weakness. Her CTMT Composite Index Description Score was "Very Superior" pre-intervention and post-intervention. On the SPM-Home Form, interpreted scores remained the same in all categories pre-intervention and post-intervention. These were categorized as "Typical" in the areas of: Social Participation, Vision, Hearing, Body Awareness and Planning and Ideas. The score of "Some Problems" was yielded pre-assessment and post-assessment in the areas of "Touch" and "Balance." The overall Total score of "Some Problems" also remained static..

Participant 1M's Fun House Treasure Hunt game logs were analyzed using SPRE and cross examined with parent communications. A change point was identified at Day 11, with an R^2 value of .57, indicating a high correlation between 1M's scores and treatment day (see Appendix K for R^2 calculations).

Figure 2 displays Participant 1M's scores plotted with respect to time, with additional future outcomes plotted after the change point. Predicted outcomes were calculated through to Day31, at which time it is estimated Participant 1M would receive maximum benefit with the use of the Fun House Treasure Hunt game. Although participant 1M's CTMT Composite Index Description Score was "Very Superior" and SPM-Home Form was "Typical", analysis using SPRE still demonstrated that this child participant could receive sensory input benefits from engaging in Fun House.

Participant 1M's parent daily logs noted the following descriptive data: Day 1 scores

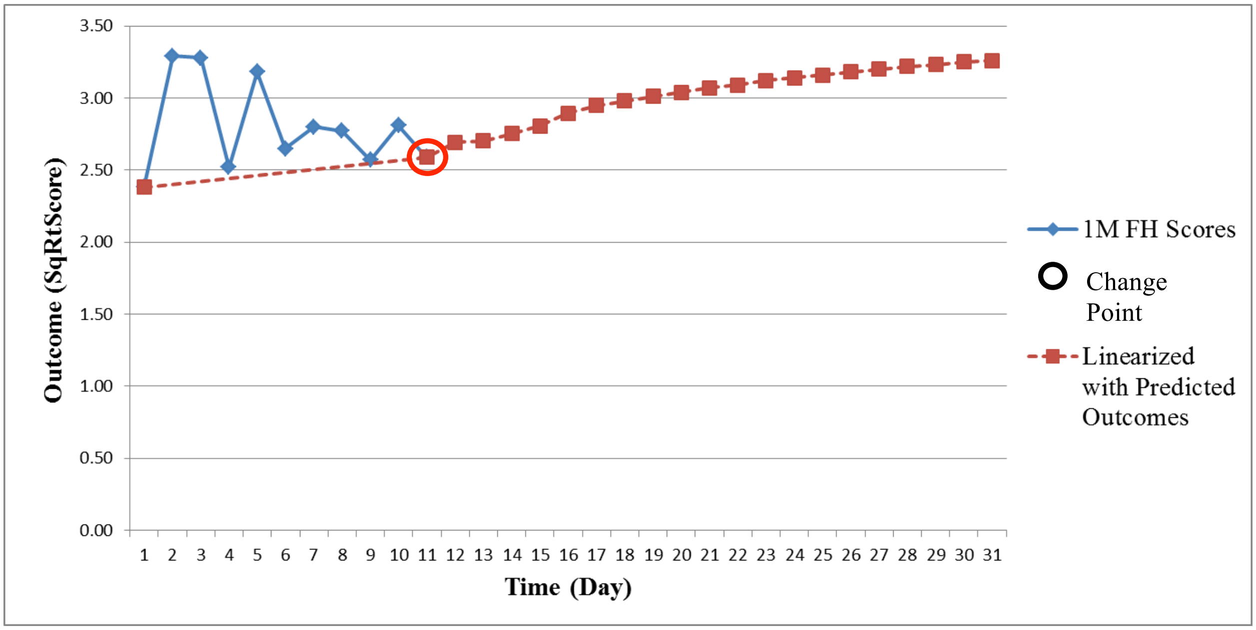

Figure 2. Participant 1M Fun House Graph with Predicted Outcomes

Participant 1M is an 11 year old female with diagnoses of Asperger Syndrome and muscular weakness. CTMT Composite Index Score=Very Superior (pre and post-intervention), SPM-Home Form=Some Problems (pre and post-intervention), Change point=Day 11, Maximum Benefit=Day 31

were taken from playing at the clinic following pre-testing in a quiet room. The next day, Day 2, the participant played at the home environment and scored her lowest score for game points. It was noted that her brother was present in the room at this time. Days 3 and 4 showed an improvement in scores and 1M's highest score was achieved on Day 5. This participant became bored of the game after the first week of game play and she seemed "disinterested and distracted." Her focus switched to looking for glitches, or flaws in the game software, during the second week of play.

Participant 1Q. Participant 1Q is an 8 year old male with the diagnoses of vestibular dysfunction, dyspraxia, and muscular weakness. His CTMT Composite Index Description Score showed an increase from "Average" pre-intervention to "High Average" post-intervention. His SPM Home Scores were "Typical" in all areas pre-intervention and post-intervention. He played Off Road Treasure Hunt for the first cycle of the intervention. On Day 5 of game play his parent observed he seemed “amped up” after playing the game. No other observations were noted other than that the Off Road game became boring towards the second half of the cycle and that the game play did not make him feel dizzy.

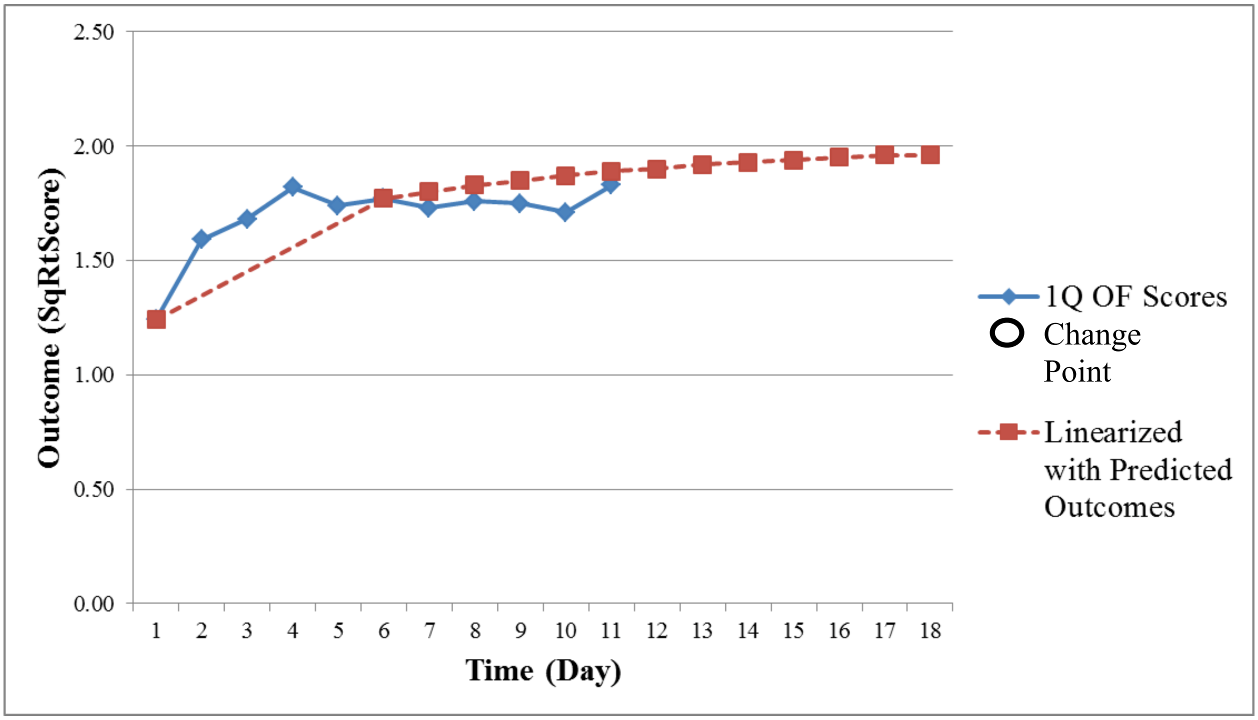

Figure 3. Participant 1Q Off Road Graph with Predicted Outcomes

Participant 1Q is an 8 year old male with diagnoses of vestibular dysfunction, dyspraxia, and muscular weakness. CTMT Composite Index Score=Average (pre-intervention) CTMT Composite Index Score=High Average (post-intervention), SPM=Typical (pre and post-intervention), Change point=Day 6, Maximum Benefit=Day 18, Percent difference in predicted outcome versus actual score at Day 11=3.28%

1Q’s Off Road Treasure Hunt game scores were analyzed using SPRE (see *Figure 3*, outcomes plotted versus time). A change point was identified at Day 6, with an R^2 value of .76, indicating a high correlation between 1Q’s scores and treatment day (see Appendix K for R^2 calculations). Predicted outcomes were calculated through to Day18, at which time it is estimated Participant 1Q would receive maximum benefit with the use of the Off Road Treasure Hunt game. Although the change point was identified as Day 6, original data scores were also available up to Day 11. Based on the predicted outcome at Day 11, the prediction was only 3.28% higher than the measured data (1.89 predicted versus 1.83 actual), providing great validity of researcher predictions and reliability of the SPRE to predict maximum benefit from game play.

Participant 1Q's scores for Fun House were plotted against treatment day in *Figure 4*. Participant 1Q's Fun House change point was identified at day 10, with an R^2 value of .65, indicating a high correlation between 1Q's scores and time. Predicted outcomes were calculated through to Day 33, at which time it is estimated Participant 1Q would receive maximum benefit with use of the Fun House Treasure Hunt game.

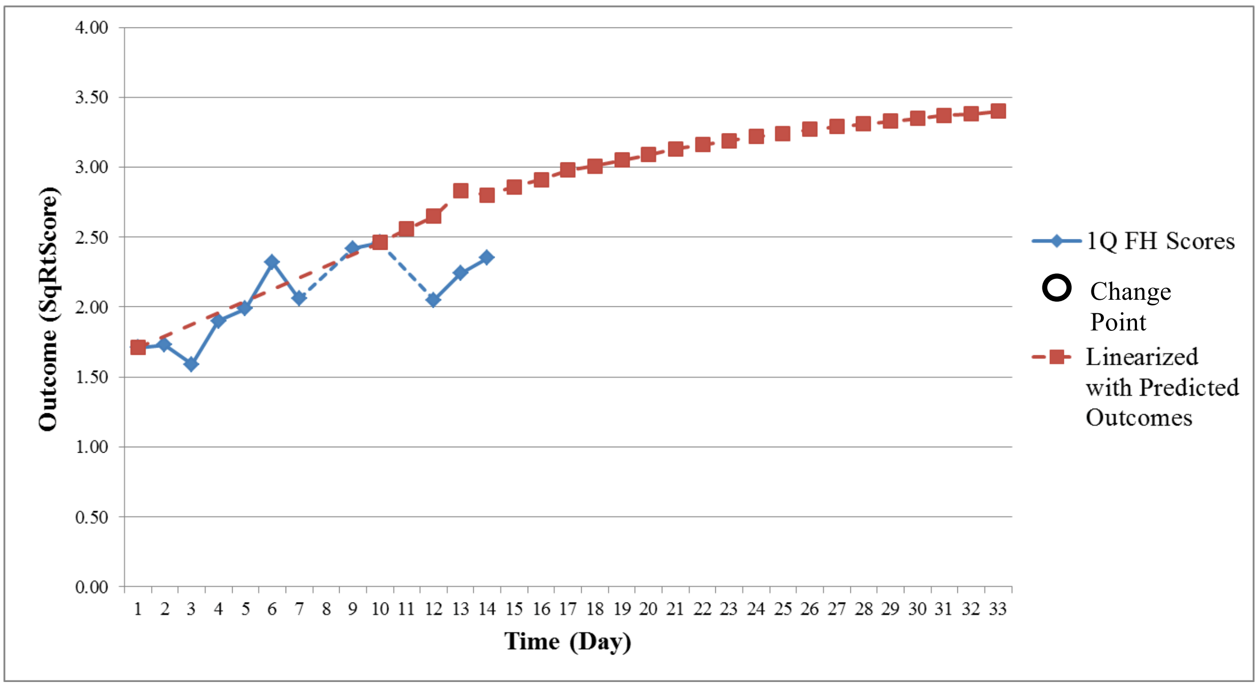

Figure 4. Participant 1Q Fun House Graph with Predicted Outcomes

Participant 1Q is an 8 year old male with diagnoses of vestibular dysfunction, dyspraxia, and muscular weakness. CTMT Composite Index Score=Average (pre-intervention) CTMT Composite Index Score=High Average (post-intervention), SPM=Typical (pre and post-intervention), Change point=Day 10, Maximum Benefit=Day 33, Percent difference in predicted outcome versus actual score at Day 14=19.15%

Participant 1U. Participant 1U is an 11 year old male with the diagnosis of Autism Spectrum Disorder. His CTMT Composite Index Description Score was "Below Average" pre-intervention and post-intervention. On the SPM-Home Form his interpreted scores demonstrate an improvement in the areas of Hearing and Balance. His Hearing score was "Definite

Dysfunction" at pretesting and rose to "Some Problems" post intervention. Participant 1U's SPM score for Balance also went up one level pre-intervention and post-intervention from "Some Problems" to "Typical." This participant's scores decreased one level in the two categories of Vision and Body Awareness. His Vision score was "Typical" at pretesting and fell to "Some Problems" in the post-assessment. Similarly in Body Awareness, his score was "Typical" at pretesting and fell to "Some Problems" in the post-assessment. This participant's Total interpreted score for the SPM-Home Form was rated the same pretest and post-test as "Some Problems."

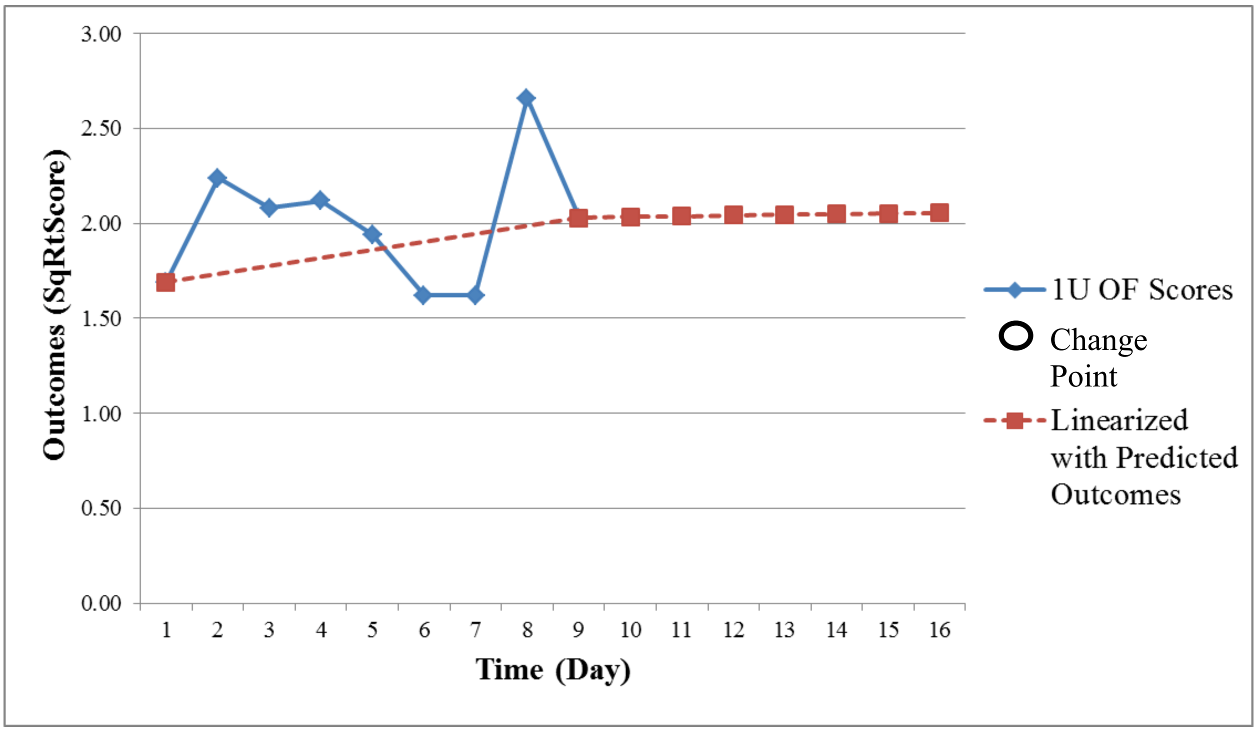

Figure 5. Participant 1U Off Road Graph with Predicted Outcomes

Participant 1U a 11 year old male with diagnosis of Autism. CTMT Composite Index Score=Below Average (pre and post-intervention), SPM-Home Form=Some Problems (pre-intervention), SPM-Home Form=Typical (post-intervention), Change point=Day 9, Maximum Benefit=Day 16

Participant 1 U's parent noted that he was always happy to play the game, but he never begged to play. At times, he seemed to get frustrated more easily and was more irritable while playing the game. During the post interview the participant's mother explained that they have a busy household with six children and the computer is in a shared space. On the daily log, she noted that when background stimuli increased during game play, he would sometimes yell, growl and bark at his family members. His mother noted that it is hard for this child to verbalize his feelings. On the final day of play he stated, "I am so glad to be done with this game!"

SPRE analysis was conducted for this participant's EASe game scores (see *Figure 5*). A change point was identified at Day 9, with an R^2 value of .10, indicating a correlation between 1U's scores and treatment day (see Appendix K for R^2 calculations). Predicted outcomes were calculated through to Day 16, at which time it is estimated Participant 1U would receive maximum benefit with the use of the Off Road Treasure Hunt game.

Participant 1Y. Participant 1Y is a 12 year old male with the diagnoses Pervasive Development Disorder, Not Otherwise Specified. His CTMT Composite Index Description Score remained "Average" pre-intervention and post-intervention. On the SPM-Home Form his interpreted scores demonstrated marked improvement in the area of Planning and Ideas, rising two levels from "Definite Dysfunction" to "Typical." An improvement was also made in the area of Planning which scored "Definite Dysfunction" pre-assessment and rose to "Some Problems" post assessment. The scores for the remaining categories covered on the SPM remained the same for Participant 1Y pretest and post-test. The score of "Some Problems" was indicated in the categories of Social Participation, Vision, Hearing, Touch and Body Awareness both pre-intervention and post-intervention. The score of "Some Problems" was also the SPM total interpreted score.

Participant IY's Fun House Treasure Hunt game scores were analyzed using SPRE (see *Figure 6*). A change point was identified at Day 14, with an R^2 value of .59 indicating a high correlation between 1Y's scores and treatment day (see Appendix K for R^2 calculations).

Predicted outcomes were calculated through to Day40, at which time it is estimated Participant 1Y would receive maximum benefit with the use of the Fun House Treasure Hunt game.

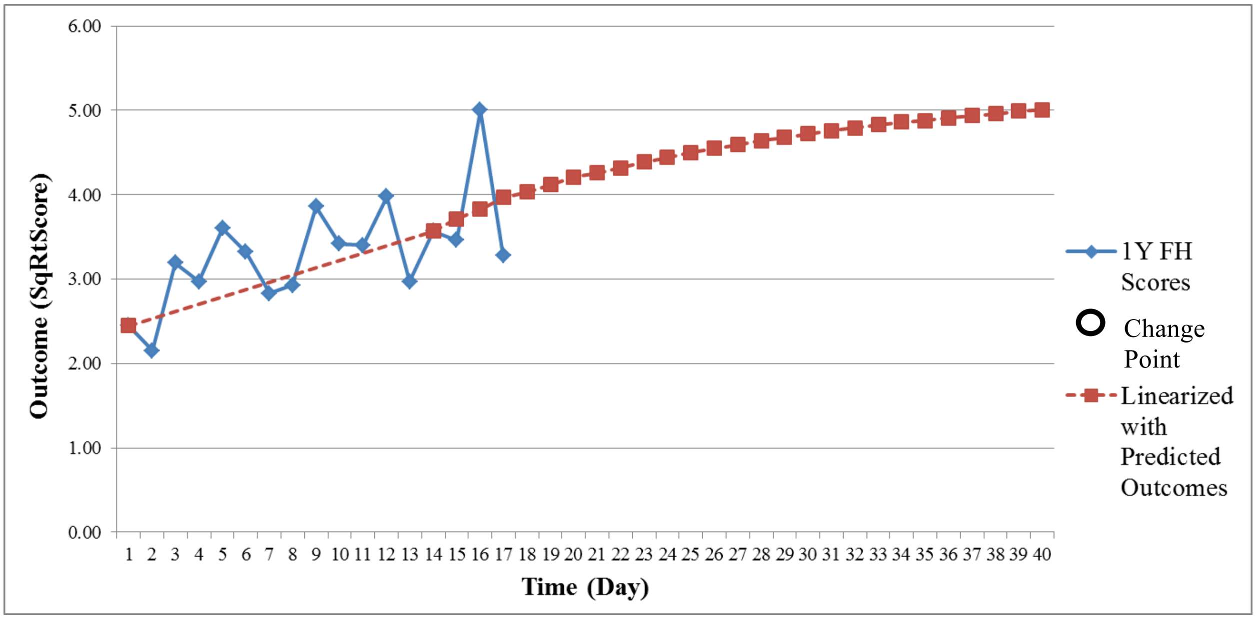

Figure 6. Participant 1Y Fun House Graph with Predicted Outcomes
Participant 1Y a 12 year old male with diagnoses Pervasive Development Disorder. CTMT Composite Index Score=Average (pre and post-intervention), SPM-Home Form=Definite Dysfunction (pre-intervention), SPM-Home Form=Typical (post-intervention), Change point=Day 14, Maximum Benefit=Day 40, Percent difference in predicted outcome versus actual score at Day 17=21.04%

Participant 1Y complained that he did not like wearing the headphones while playing the EASe games. After removing the headphones he enjoyed playing the game. He reported that his legs felt "shaky" after playing the game for 3 days in a row. Participant 1Y's parent liked that the EASe program was easy to use at home. It was observed that his behavior improved somewhat following the EASe game intervention; he seemed more compliant than he had been previously.

Summary of Results

With this pilot study, the researchers had hoped to explore the effect of the EASe video games which purport to provide visual and auditory sensory input to improve sensory processing skills. The researchers aimed to answer the following questions: Will the use of EASe games for 28 days, twice a day for thirty minutes improve a child's visual attention, spatial organization, praxis, social participation, vision, hearing, touch, proprioception, vestibular function, or sensory processing skills resulting in lower scores on the Sensory Processing Measure-Home Form (Parham & Ecker, 2009) and lower scores on the Comprehensive Trail Making Test (Reynolds, 2002)?

Improvements in pre-assessment and post-assessment and game scores as well as child and parental feedback would allow for a recommendation for the use of these games for pediatric clients with differences in sensory processing. The SPRE analysis would provide occupational therapists with a predictive measure of the number of treatment days, if any, which would be needed to make the maximum improvement in the integration of sensory skills for each participant (see a listing of predicted outcomes to the point of maximum benefit for Fun House and Off Road participant scores in *Table 5* below).

Table 5
Participant Individual and Means Data Table

Participant ID	Game Played	Change Point	Day of Maximum Benefit	% Increase from the Change Point
1I	Off Road	13	22	14.14%
1M	Off Road	6	18	14.40%
1Q	Off Road	9	9	--
Mean	Off Road	8	22	7.01%
1Q	Fun House	11	31	20.67%
1U	Fun House	10	33	27.62%
1Y	Fun House	14	40	28.67%
Mean	Fun House	7	27	29.76%

As indicated by *Table 5*, the maximum benefit of game play for the Fun House Treasure Hunt game ranged between days 31 – 40, indicating a high length of playability for participants 1M, 1Q, and 1Y. The maximum benefit from Off Road Treasure Hunt would result between days 16 – 22 for participants 1I, 1Q and 1U. When comparing participant 1Q's predicted scores, 1Q's Fun House maximum benefit was calculated at Day 33, when 1Q's Off Road maximum benefit was calculated at Day 18. These predictions are supported by qualitative data presented in the parent daily logs, suggesting that Fun House is much more engaging and interactive than Off Road which, with this added motivational factor, could potentially interest a child for a longer period to promote a higher level of sensory desensitization.

According to the Semiparametric Ratio Estimator (SPRE) results using game logs from the Fun House participant 1M would reach a maximum benefit of playing Fun House at day 31, 1Q at day 33, and 1Y at day 40 (see *Figure 7* below) which indicates that at this day, the child

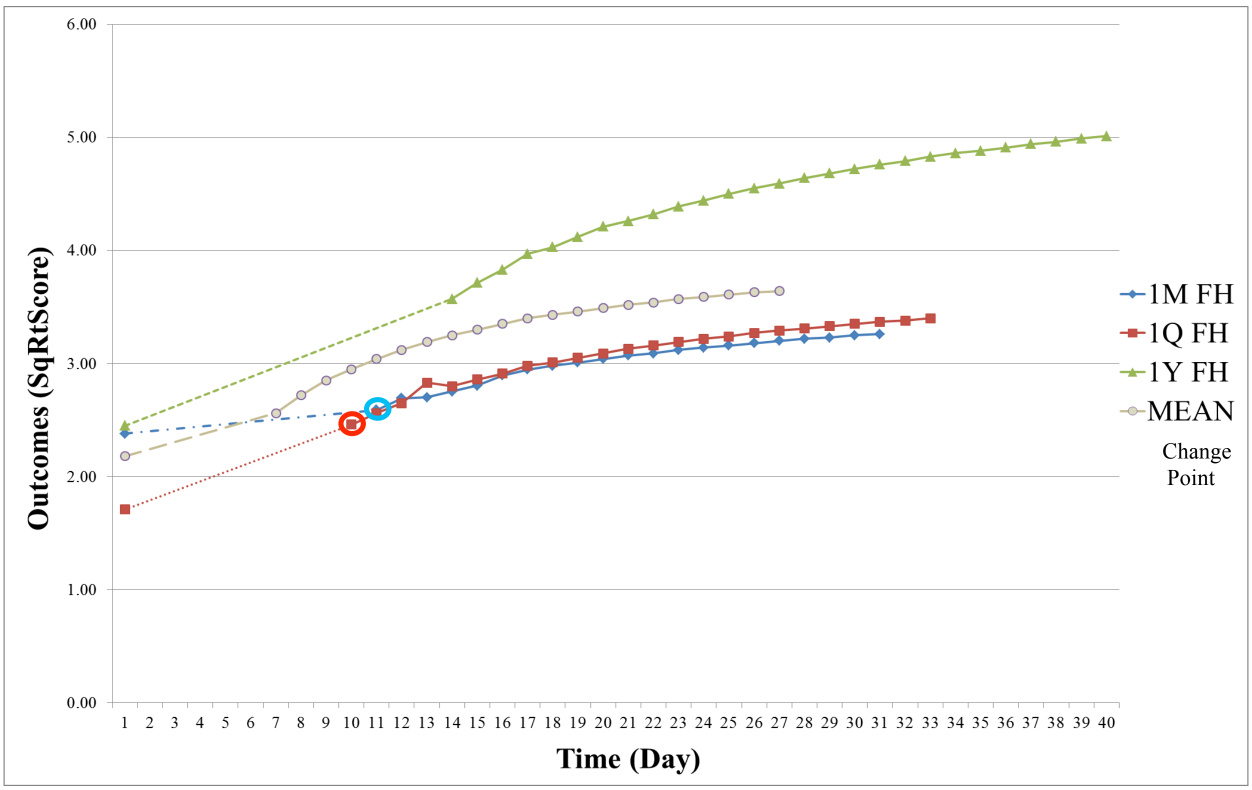

Figure 7. Fun House Mean of Participants Graph with Predictions

participant has developed a significantly increased tolerance to engage in EASe games and listen to the accompanying modified music. With the Semiparametric Ratio Estimator, occupational therapy researchers have the capability to view the mean of the participant's scores plotted over the individual scores (see *Figure 7* and *Figure 8*).

To compute mean scores, researchers found the average of each of the three participant datasets for each day and predicted outcome. From these averaged values, the researchers followed the same procedure used for each individual dataset, by completing a linear regression to find the change point of the mean data. Data was then analyzed using the SPRE model to predict mean outcomes to the day of maximum benefit for each participant. In *Figure 7*, the mean data of the Fun House datasets is graphed along with each individual's scores, and falls within each, where it is expected to be. In *Figure 8*, the mean data of the Off Road datasets is graphed along with each individual's scores, but stretches above the line of the participant with the highest scores, not within the range of the three individual participant scores. This unusual

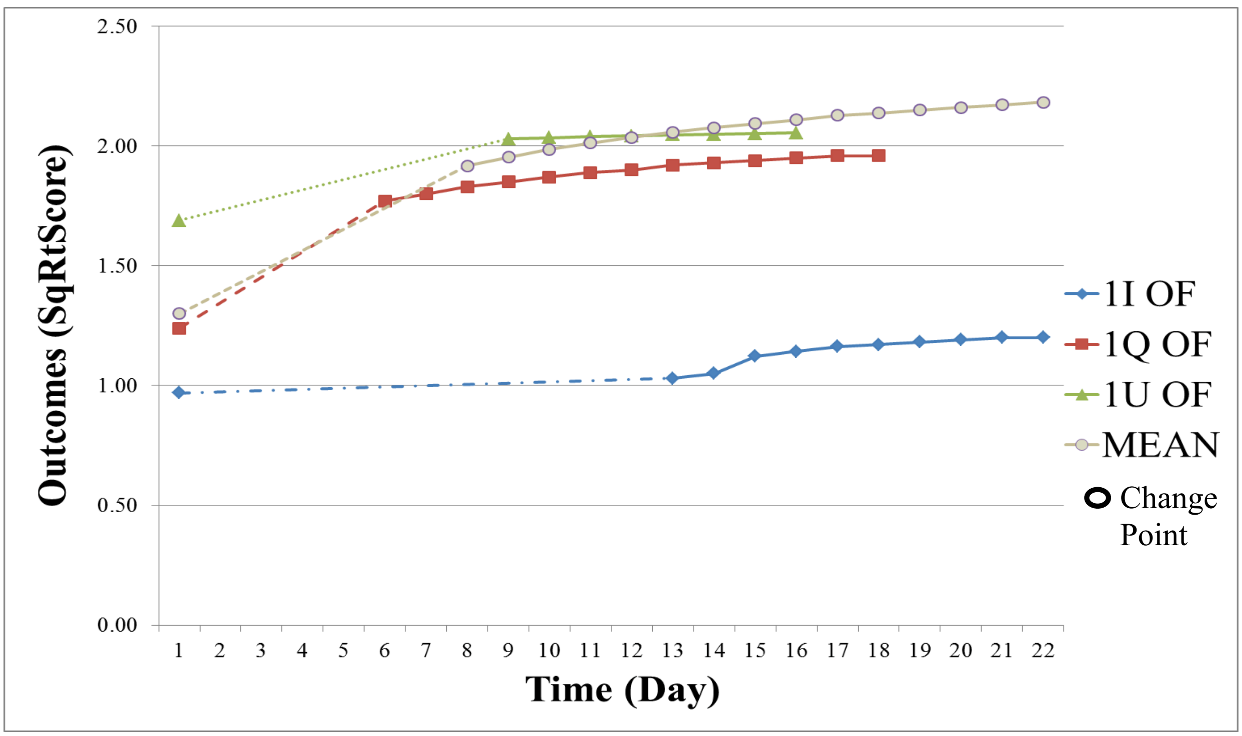

Figure 8. Off Road Mean of Participants Graph with Predictions

representation suggests that the individual data is inconsistent between participants as well as between participant scores and the mean scores. This analysis of the means allows researchers to comment on how well the mean predicts (as in *Figure* 7) or does not predict (as in *Figure 8*) these individual scores, and whether the data can be generalized across the population.

CHAPTER 5

DISCUSSION

Interpretation of the scores from the game logs provided by the EASe games suggests that child participants, aged 8-12 years, exhibited modulation of auditory and visual sensory input. The game data revealed that the child participants were able to better tolerate modified music and game play of the EASe Fun House Treasure Hunt game more so than the EASe Off Road Treasure Hunt. There are several possible explanations for the findings. The researchers examined all of the data collected on each child including the standardized testing results with Comprehensive Trail Making Test (CTMT) and Sensory Processing Measure (SPM), EASe game score logs, parental observations, and notes from the post interviews with families. In particular, 1A and 1U had the most difficulty per parent log with the Off Road game (as displayed in *Figure 5* for 1U, and *Table 4* for 1A). For example, both participants displayed irritation from game music, frustration, and attention difficulties. Qualitative data provided by parent logs and interviews was found to be consistent with the game log data and SPRE analyses.

Interpretation of the Findings

Participant 1A had erratic Off Road game scores which showed little improvement in tolerance to the EASe game. A close examination of all the data collected for this participant was made to determine why this player's results and graphs of game scores stood out from the rest. It appears that Participant 1A was unsure of which setting of the Off Road game he preferred at the start of the two week cycle. For the first few days he switched back and forth between the two landscapes – Open Savannah and Red Rock range in the Off Road game, while the other two participants played their assigned game, as per study protocol, for the majority of the game sessions. This switching back and forth between settings provides some explanation for 1A's inconsistent scores on Days 1 and 3 when he chose to play Open Savannah part of the time. Nonetheless, his scores remained erratic once he chose to play Red Rock only beginning on Day 4.

Removing the headphones may have had a positive impact on this participant's overall score for Day 2. The increase in his game score is also likely the result of having practiced the game the previous day. On the evenings of Days 2 and 3 the participant's sensory system may have been overloaded by this point in the day, making it seem more challenging to complete and "seem longer" during the evening sessions (Brown & Dunn, 2010). By the second session of Day 3, the participant had likely acclimated to the music incorporated into each game to a degree because he reported that the music was no longer bothering him which appears to demonstrate improved ability to process the modified EASe music. Additionally, he had free time in the afternoon to recover from any overstimulation accumulated throughout the day before playing the second daily session. The game play protocol also calls for use of the mouse. This challenge may have negatively affected his score on Day 4. Participant 1A seemed to no longer enjoy playing Off Road beginning on the sixth day as evidenced by the decrease in play time and choosing music rather than game play when his parent was not home.

By cross-referencing individual player's scores with their parents' written notes, specific contextual factors affecting the children's performance were revealed. For instance, both participant 1M and 1U were negatively affected when playing the game in close proximity to their sibling(s). Participant 1U, whose scores showed little improvement, was playing the game in a busy household setting for the majority of the sessions. This was contradictory to the researchers' instructions to play in a quiet setting with minimal distractions. The time of day was a factor for the participants as well. It was clear that one player's scores increased after taking ample time to rest or settle down from his school day (see *Figure 5* for display of 1U's scores). These observations are concurrent with Brown and Dunn's postulations that sensory thresholds exist and that context influences one's behavior (Brown & Dunn, 2001).

It should be noted that the majority of the participants whose EASe game scores were examined reported that they became bored with game play prior to the end of each two week cycle. The intent of game developer, William Mueller, was for children to be able to choose from a variety of games to continue their interest in the games. He predicted that the children in this study would become bored if they were limited to one game (Mueller, 2011). As this is a pilot study, the researchers chose to have participants play only one game throughout each two week cycle to reduce the number of variables and to maintain a controlled study.

It is significant that from this group of participants, randomly chosen by the biostatistician who was blinded, that all five preferred the Fun House game, as indicated in the parent logs. When interviewed, two of the children expressed that Off Road was too easy and that they became bored. Fun House is a more complex and difficult game than Off Road, and is also the more interactive of the two games (Mueller, 2011). One of the participants shared that Fun House was, "much more exciting because it had elevators, and you could go to different rooms, and there were trampolines and ball games. Off Road was always the same—the groups of treasures just changed colors." These comments correspond between participants indicating that the children were engaged for a longer period while playing Fun House than when they were in the Off Road cycle, thus receiving more benefit from the Fun House game. This was also indicated by the mean and low *p*-values represented by the Fun House scores which can be generalized to a larger similar population.

Children who played the Fun House game likely benefited from more sensory desensitization than those who played Off Road, as evidenced by longer play times and increased scores as they progressed through the game play. Although the music for the two games was encoded in a similar manner, the songs were different. Perhaps the audio for the Off Road game was more unsettling for the participants than the audio for Fun House, making the Off Road game less appealing. It is suggested that future researchers explore the differences between the musical selections of the two games by closely monitoring each child's response using quantitative and qualitative analysis.

Another plausible explanation for the children's preference for the Fun House game is that in this game, the player is confined to "rooms" within the "Fun House" while the environment in Off Road was open and there was more virtual space between treasures. It was easy to "get lost" in the Off Road game because the virtual environment is created in an expansive desert space. For these reasons, the participants were receiving positive reinforcement sooner and more often in the Fun House game.

Two of the participants who played Off Road went after the treasures the first several days and then became interested in exploring the environment and looking for glitches in the game per parent logs. Bill Mueller, developer of Electronic Auditory Stimulation Effect (EASe) games encourages "wandering" in the games if this is what the player prefers to do. He stated it was not his intent to limit the children's focus to attaining points because each child is unique and should be able to follow their interests (Mueller, 2011). Mueller's suggestion is supported by the research of Bundy, Shia, Qi, and Miller (2007). These researchers examined the relationship between children diagnosed with Sensory Processing Disorder and the occupation of play, and found that both the control group and the group with sensory processing deficits were found to be "extraordinarily playful" (Bundy et al., 2007). As stated in Chapter 2, all children are naturally motivated to play, but they select activities according to their capabilities and sensitivities. Family reports indicate that the participants were more motivated to play Fun House Treasure Hunt than Off Road Treasure Hunt, regardless of the order in which the games were played.

Although the SPM and CTMT scores were not used as originally intended for analysis within this study, test interpretative category results did improve one to two levels for some of the six chosen participants on the CTMT. Pre and Post-intervention test scores using these measures also indicated some instances of regression, minor, or no change. Researchers used SPRE analysis to analyze the amount of maximum benefit participants would receive engaging in interactive games Fun House and Off Road. The researchers felt these results would provide a more practical application on the games' therapeutic benefit. It was found that this method of analysis could track an individual's progress and identify length of treatment sessions required for a change in performance and maximum benefit derived from game play.

The results of this study provide evidence that further studies on the use of the EASe games to improve sensory processing deficits are warranted. Further studies could potentially provide evidence to substantiate reimbursement for using EASe games within services provided under the guidance of an occupational therapist. Upon reflection, best occupational therapy practice would have been to conduct post testing using the SPM and CTMT assessments initially after intervention and again at 3 to 6 months in order to explore true changes in sensory processing and attention using these measures.

Implications

The EASe games serve as an appropriate therapeutic home program, as evidenced by the family reports and responses of the children in this study who were able and motivated to play these games independently. Some parents reported that they enjoyed the fact that the EASe games were easy for their children to use at home without the requirement of direct supervision. Both EASe games, Fun House Treasure Hunt and Off Road Treasure Hunt, can be used as teaching tools for parents and therapists and to begin a conversation about coping strategies for children with sensory sensitivities such as defensiveness. It is recommended that children who have significant sensory and/or cognitive deficits begin playing EASe games under the supervision of an occupational therapist and progress to playing independently as the child becomes more accustomed to the program. When EASe games are used during a therapy session, an occupational therapist can provide the child with redirection, hand-over-hand assistance, or verbal cues for difficult aspects of the games.

These games, as analyzed by the Semiparametric Ratio Estimator (SPRE), can be used to determine a child's current and future potential progress. In this study, game scores were also analyzed to identify the number of days of treatment necessary for each participant to obtain the maximum benefit of modulation of auditory, visual, and vestibular sensory input provided in the EASe Off Road and Fun House games. As indicated by the SPRE analysis of game play using the Fun House game, child participants 1M and 1Q would reach a maximum benefit at Day 34 of intervention, and 1Y would reach a maximum benefit at Day 40. These results indicate that child participant 1Y requires six more days of playing the Fun House game before he/she can tolerate the modified music using the spatial organization, and visual tracking needed to complete the game levels.

When reviewing results of the mean of these three participants, the overall point at which one can expect a change in toleration of sensory input from the game is at Day 7, with the maximum benefit averaging at Day 27. This information is highly valuable for therapists, as it can be used to inform their practice and enables them to ascertain how much therapeutic intervention time or how many therapy sessions would produce the maximum benefit of sensory modulation for each child. These mean results produced by the SPRE analysis suggest that therapists will likely not see change in response to the EASe Fun House game until Day 7 of intervention, and that children should continue through at least 27 days of intervention using these products in order to receive maximum benefit. This analysis also provides quantitative information for setting realistic intervention timeframes for reimbursement of therapy services using these products.

The SPRE analysis for Off Road Treasure Hunt mean scores does not show the same degree of benefit from playing this EASe game, as individual participant data were inconsistent and resulted in an inaccurate mean representation. Reasons for this inconsistent data may be due to differences in the settings in which the game was played, boredom and switching between settings with varied levels of difficulty (“Open Savannah” and “Red Rock Range”).

When EASe games are used with children, the child is made aware that he/she can stop the game if the sensory input becomes overwhelming, e.g. the child experiences headache, nausea, or irritability. In such cases, children may return to game play at a later time, when the child feels ready to do so. If children can learn to monitor their responses in their daily lives in the same way, this self-awareness skill can be of great use to them as they learn to manage sensory input. As a result, they will likely experience less emotional breakdowns, tantrums or other negative reactions in response to sensory overload, and will instead experience improved success in their occupations of learning, socializing, and playing (Dunn, 2001).

Recommendations for Future Research

In this exploratory study, many lessons were learned that are passed on to future researchers using EASe games as an innovative adjunct to intervention as well as SPRE as a data analysis tool that best fits measurement of human performance in this context. One objective of this pilot study was to develop recommendations for future EASe product research study methodologies. This was the first study conducted on the EASe games using a population of child participants. Additionally, this is the first study to use the Semiparametric Ratio Estimator (SPRE) to compare mean scores to the exact individual scores from which they were taken. It is suggested that future studies be conducted using SPRE to analyze the effect of the EASe Off Road Treasure Hunt game scores separately for "Open Savannah" and "Red Rock Range". Researchers can assess differences, such as how much more challenging the Red Rock Range is than Open Savannah by comparing the data between the two settings between or within subjects or subject groups. Once this is determined Red Rock scores can be graded according to level of difficulty.

Recommended protocol for future studies using EASe products include a requirement that researchers become familiar with the EASe video games by playing a minimum of thirty minutes of each game before conducting studies with the games. It is also suggested that researchers conference prior to conducting game sessions to brainstorm and discuss any questions regarding game set up, play, or complications that might occur, such as how to handle possible behavior issues of participants which might arise secondary to several factors. These include sensory deficits or sensitivities that are co-morbid to diagnoses such as Autism Spectrum Disorder or Down syndrome, behaviors in context such as clinic-based work versus, and home-based programs.

One positive feature of the EASe games is "user-friendliness" in the home. Suggestions for future research using pre-existing caseloads include collecting accurate participant data such as confirmation of contact information and occupational profiles. It is also suggested that EASe follow-up studies be conducted during a time when school is not in session. Ideally, this would occur during school season breaks longer than two weeks or in the summer. Many of the families initially contacted for inclusion in the study were under the impression the intervention would occur during the summer term. Interest level fell significantly when parents learned the intervention would take place during the first month of school secondary to extracurricular activities and high level of homework assignments some child participants would be experiencing. Some families who were initially interested in participating in the study opted out for this reason and others agreed to continue participating only after being told children had the option to listen to the EASe music in place of playing the games if necessary.

Finally, researchers are advised to learn and use the SPRE program. The researchers conducting this study were fortunate to have access to and training with the developer of the SPRE program. It is also recommended that the researcher group train on, meet with and conference with the developer of EASe games to discuss issues or questions which might arise as a result of game play. For example, it was found during conferencing with our biostatistician, Dr. Weissman-Miller that 9 game sessions generated from games logs were needed for analysis using the SPRE program as opposed to the originally anticipated 14 sessions. The researchers expect EASe products would demonstrate a significant relationship with improving sensory deficits in future studies as organized according to the recommendations generated by this study.

Conclusion

The hypothesis that the use of Electronic Auditory Stimulation Effect (EASe) games for 28 days, twice a day for thirty minutes would significantly improve a child's visual attention skills, spatial organization skills and occupational performance at home, as measured by EASe game tracking scores was supported by the significant predicted outcomes calculated using the Semiparametric Ratio Estimator (SPRE).

The researchers consider the predictive validity of SPRE as a noteworthy finding of this study. As seen with participant 1Q in the Off Road dataset, the change point was identified as Day 6, although data was also available up to Day 11. Based on the predicted outcome at Day 11, the prediction was only 3.28% higher than the measured data, providing great validity of researcher predictions and reliability of the SPRE to predict maximum benefit from EASe game play. Our results conclude that EASe interactive games, Fun House and Off Road, provided multi system sensory input that promoted improved sensory modulation as evidenced by the percent increase in the participants' ability to habituate to interactive EASe game play.

Furthermore, this is the first instance in the field of occupational therapy research, of which the researchers are aware, where a study's results using SPRE to analyze data provide comparisons of the group mean to the exact individual scores from which they were derived in order to examine how well the mean reflects the individual responses to the EASe games. The findings of this study conclude that, based on Fun House means predictions with a *p*-value of .024 and a high R^2 at the change point, the benefit of using EASe games and music compact discs seen in this study's participants could be generalized to the greater population of children with sensory sensitivities.

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