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Developmental trajectory of postural control during various sensory conditions in typical and atypical children.

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Developmental trajectory of postural control during various sensory conditions in typical and atypical children.

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Dedicated to the loving memory of Afton Pettey

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Developmental trajectory of postural control during various sensory conditions in typical and atypical children.

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The University of Texas at Austin, 2010

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Developmental delays are known to exist in children with autism when compared to their typically developing peers. Foundations of these delays stem from the cognitive and motor performance realm, but information regarding specific characteristics, such as postural stability and sensory integration, are less defined. In this study, postural stability differences were investigated between children with autism and neurotypical children. Past research has shown the role of sensory integration during postural sway has been a strong indicator in showing developmental progress. Due to the focus of the protocol being on static balance, the Modified-Central Test of Sensory Interaction for Balance was used to measure postural stability. The age range for this study is set between 3 and 5 years of age and follows CTSIB protocol to assess 32 neurotypical developing children and compare their results to an archived data set containing CTSIB results from a sample of children with autism. Results from the study indicate that when the autism and neurotypical groups were compared, no significant main effect was found. Developmental differences were found across age groups in that 5 year olds displayed more stability than 4 year olds, but there was no difference between 3 and 4 year olds or 3 and 5 year olds. Further analyses of these developmental results indicated that children in the neurotypical group follow an expected developmental progression while children in the autism group display a divergence from this typical progression. Findings of this research add to the existing literature that children with autism display inconsistent developmental patterns which have a strong relationship with the delayed activity levels of these children. The knowledge and understanding of these delays will allow practitioners to implement specially designed programs to ensure that these children receive the activity that they need and deserve.

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Chapter One

Introduction

Balance is essential to physical independence and voluntary movement control. Not only does balance define our ability to remain stable while static, but intricate patterns of muscular coordination across the body allow for the completion of purposeful dynamic movements as well. The acquisition of balance skills is a largely transparent process chronicled in the achievement of motor milestones during the first years of life. Children with disabilities, however, do not follow the typical developmental path. In this study, we investigated the control of balance in a group of typically-developing children and compared their performance with children diagnosed on the autism spectrum (ASD). Children with ASD are not diagnosed based on delays in motor development, but motor dysfunction is characteristic of most children with autism and therefore in this study, we focused on early balance control skills. The understanding of differences between children with autism and typically-developing children will lead to the advancement of rehabilitation strategies and interventions. Therefore, the procedural nature of development must be deconstructed into its individual stages in order to create a finite procedure that will endure and cooperate with body change and growth.

Across the stages of development, it is the integration of sensory inputs – visual, vestibular and somatosensory feedback – that assists in the learning and mastering of an action. The integration of our body's senses becomes vital in this process. In order for the developing child to fully comprehend the environment around them, their ability to manipulate, control and understand sensory feedback will ultimately lead them to their goals. The importance and power of sensory integration is observed perfectly in a simple task such as standing.

On the contrary, atypically developing children (e.g., children on the autism spectrum) experience a much different developmental process (Fein et al., 1984; Minshew, 2004; Hauk et al., 2001; Rinehart et al., 2001). The in-depth history of autism development research has shown various levels of motor development delays in this population. For instance, it has been shown that children with autism are delayed in hand preference and often experience “ambiguous handedness” as compared to typically developing children (Fein et al., 1984; Hauk et al., 2001). In the study by Fein et al., (1984), authors defined the lack of hand preference as a *developmental lag* which inevitably leads to the delay of fine motor skill development. Although children with autism are not diagnosed on the basis of motor performance and proficiency, it is suggested that these children experience a level of “clumsiness.” In order to determine the origin of this, Rinehart et al. (2001) defined children with autism as having “atypical movement preparation” that stems from a “lack of anticipation.” The building blocks of sensory function have been examined and show that not only do delays in sensory function exist in children with autism, but these delays exist for the remainder of the individual’s life (Minshew, 2004). With this evidence of the differences that individuals with autism face during development, the focus of this study was placed on early childhood and where, or even if and how, these children differ from the typical developing model.

In both typical and atypical populations, before any level of dynamic ambulation comes the foundation of stance. Skill in balance is a motor development trait that is displayed in the typically developing population, but this may not be the case for those who develop atypically. Although the action is minimal in its movement, there remains a high demand on the body in order to maintain equilibrium. Sensory systems, such as the visual, vestibular and somatosensory, play a key role in understanding the environment and physical location of the body. Vision allows an individual to develop a frame of reference for their surroundings whereas vestibular function relies on inner body feedback in order to maintain equilibrium. In the somatosensory system, its subsets such as proprioception assist in the recognition and positioning of the body. Thus, one can imagine the difficulties atypical children face during the developmental process if this system does not integrate appropriately. Proprioceptors within the body not having the ability to properly interpret information received are like having a machine with no fuel or a pen with no ink. The system becomes useless when its functional capacity does not exist and therefore added pressure is placed on different systems to carry out the needed function. Human development places emphasis on making adaptations: we use a pencil when we're out of ink, we ride our bike when we are out of fuel and individuals who are blind rely on other forms of sensory information such as touch and hearing in order to function. These adaptations and dependencies are clearly the key to sensory integration development, but the question remains how typical and atypical children compare in their integration and utilization of the sensory system.

The process by which typically and atypically developing children depend on each of these feedback methods during postural stability can be explored by simply administering tests that challenge each of these sensory systems. Assessment tools designed to measure sensory feedback during balance have in fact distinguished the differences that exist throughout development and how each of the sensory systems matures with age (Shumwaycook & Horak, 1986). But how do these sensory integration techniques differ between typically and atypically-developing children early in development? Does manipulating the availability of sensory information have a different effect on the postural stability in children with autism when compared to their typically developing peers? These questions are only the start to the discovery of improved rehabilitation and intervention methods for children with disabilities.

In this study, postural stability and sensory integration were assessed in a group of typically developing children and compared to a population of children with autism. Each group was assessed with the modified Clinical Test of Sensory Interaction and Balance (CTSIB). This particular assessment tool is designed to manipulate the sensory systems and provide results that explain the strategies that each individual child utilizes during their development. Therefore, comparison of postural control in children with autism and children with typical development using the CTSIB provided essential information to the understanding of the autism spectrum. It was hypothesized in this study that children in the autism group would have a significantly higher sway velocity in each of the four conditions of the CTSIB when compared to the children in the neurotypical group. This difference was expected to provide evidence that delays in sensory integration during postural stability is present in children with autism.

Chapter Two

Literature Review

Variations in development: typically developing children and children with autism.

Delays observed in children with autism have a foundation at the cognitive level. A variety of assessment strategies and tools are used in order to determine the severity and functional level of these children. Testing instruments such as the KBIT-2 (Kaufman & Kaufman, 2004) is just one example of an assessment that evaluates the cognitive level of an individual on an IQ scale. Results from the test are compared to a provided table of percentile rankings that assist in determining where the individual is placed on the cognitive spectrum. Typically, children with an intellectual disability are determined to have an IQ of lower than approximately 70 as stated within the *Diagnostic and statistical manual of mental disorders* (2001). Tests such as the aforementioned KBIT-2 encompass both verbal and non-verbal sections of the assessment. Although it is important to note that not all children with autism display intellectual disabilities, the verbal delays that the population display inevitably result in lower scores due to verbal sections of assessments (Hagberg, Miniscalco, & Gillberg, 2010). Implications from these IQ scores could be that because these children show delays in cognitive function, motor control impairments exist (Hartman, Houwen, Scherder, & Visscher, 2010). Because of this, the majority of the focus in investigating these delays has been on the understanding of fine motor skills and their association with other intricate systems of the body.

With all motor skills being integrated within our neurological basis of the body, heavy reliance is placed on the sensory systems. Ultimately, the use of various assessment tools in typical and atypical populations leads to a deeper understanding of how the array of systems are integrated with one another. For example, the previously mention CTSIB can be utilized for both typical and atypical children due to is simple administration and brevity. The combination of trials short in duration and an absence of any external perturbation make the testing protocol ideal for children, especially those in the autism spectrum. As will be later discussed, several studies have displayed how the original and modified versions of the CTSIB have distinguished the sensory integration differences in postural stability in both typical and atypical populations (Shumwak-Cook, 1986; Crow et al, 1992; Dietz, et al, 1992; Hsu, 2009; Molloy et al, 2003). Along with these assessments, variations of testing in balance strategies such as dynamic posturography have also been used in order to evaluate the effects of change in environment (Cumberworth et al, 2007; Hirabayashi et al, 1995). While these two different testing strategies share similarities in the evaluation of static balance, the central difference that exists is the use of external perturbations in dynamic posturography. In a test such as the CTSIB, the incorporation of surface change (foam pad) and vision restriction (closing eyes) during certain testing conditions isolates which particular sensory systems are being used. For example, while the participant is standing on the foam pad, the somatosensory system is challenged due to the instability of the surface without typical variations in plantar pressure or muscle stretch.

Even though the testing conditions are highly experimental and are somewhat "unnatural", the implications for the child's performance can be seen in several scenarios. Somatosensory integration can be seen in static situations such as standing on an unstable and undulated surface similar to sand, or in dynamic situations such as changes in surface conditions that are often experienced during walking. Moreover, the absolute vacancy of vision that takes place in two of the CTSIB conditions is arguably the more extreme sensory manipulation. With the postural sway information collected during these conditions, there is insight to the sensory integration of populations outside of this particular study, especially those who are blind. Feedback systems, both in the internal and external context, are essential to human development and determine how we interact with the environment around us. Understanding the intricacies of each of these systems helps us understand how to improve the senses that we possess as well as operate with senses that may be absent.

Sensory integration development in typical children.

Postural control research has a unique history in regard to the development and utilization of various sensory feedback systems. Cumberworth et al. (2007) investigated the maturation process of balance systems in children and determined the various sensory feedback systems within different age groups. Dynamic posturography was measured with the use of the EquiTest system which has six separate sensory testing conditions defined as the Sensory Organization Test (SOT). Results from the SOT were scored on a scale ranging from 1 to 100 with a higher score translating to increased stability. The study measured 60 children (32 boys and 28 girls) with a mean age of 10.2 (youngest 5.08 and oldest 17.2). Analyzed data show a significant positive correlation between an increase in age and increase in stability score on the SOT. Sensory feedback strategies were focused in 3 separate categories: visual, vestibular and somatosensory. Visual scores increased significantly with height and vestibular score increased significantly with age, while somatosensory scores were shown to have no relationship with age. These results suggest that somatosensory information processing is developed at adult levels during early childhood, but an increase in height and age is a significant determining factor in regard to visual and vestibular information processing, respectively.

Prior research by Riach et al. (1987) stated that balance strategies begin to appear at age 7 and mastery of equilibrium is not established until age 16, however, results from the Cumberworth study were not able to fully support the progression of balance development based on age. With this said, it can be concluded from the aforementioned studies that as children develop anthropometrically, the reliance on vision to maintain stability decreases while the somatosensory foundations are established at a young age. Even with knowing the developmental progression of visual reliance in balance, there still remains a void in the complete understanding of somatosensory development. Although the previously mentioned authors have stated that somatosensory awareness reaches adult levels at a young age, the lower cutoff for age in these studies has been 5 years and therefore disregards those younger than 5 years old.

Similar to the Cumberworth study, Hirabayashi et al. (1995) also measured dynamic posturography in 112 children using the EquiTest System, with the intent to discover development of sensory feedback in 6 different conditions. Each of the age groups, starting at kindergarten (3 to 4 years) and going to junior high school (14 to 15 years), in the study were equally divided into 5 boys and 5 girls with the purpose of establishing sensory differences between sexes. The only significant difference between genders were found in the 7-8 age group which displayed that girls were superior to boys in utilizing vestibular cues at this point in development. Previous work has cited the change in sensory reliance during this age range as well (Shumway-Cook, 1985), but this particular study is unique in finding the difference between sexes. Results regarding sensory feedback were mirrored with those from the previously mentioned Cumberworth study in that somatosensory function was measured at adult levels during early childhood, while visual and vestibular function continue to increase with age.

Although the most significant difference between the Cumberworth and Hirabayashi studies is the focus of gender, the reporting of a difference in only one age group (7-8) of several tested provides information that both boys and girls develop balancing techniques at nearly the same rate. Thus, the key variables in determining somatosensory and visual reliance during balance in the previously mentioned experimental designs remains to be defined as age and height, respectively. However, because neither of the designs includes children younger than 5 years, a level of skepticism remains present on whether or not this information is applicable to the younger age groups.

While the focus of Cumberworth, Hirabayashi, and other researchers was to answer questions regarding the maturation of sensory feedback in relation to equilibrium, other research has inquired about the role of kinetics and kinematics in postural stability. The purpose of this work has been to further investigate the variables that are used in particular tests, such as the aforementioned SOT. Although results of these tests are presented in the form of scores during certain conditions, the value of these scores are derived from kinetic measurements such as location and movement of the center of pressure (COP) and center of mass (COM). Understanding the variable components of a test battery is essential in fully understanding how performance is measured within the battery as well as the effect each condition has on the variable.

In regard to kinetics, measuring center of pressure displacement during stance provides yet another detailed measurement for discrete movement. Sakaguchi et al. quantified the development of postural stability in children by comparing center of foot pressure (COF) to movements of the head (Sakaguchi, 1994). Subjects were arranged in 6 age groups ranging from 4 to 18 and data was also collected on 21 young adults (age 20-28 years) in order to create a comparison group. Force data and head displacement were collected on each subject while each individual stood quietly during 2 different conditions (eyes open and eyes closed) for 60 sec. The ratio between head movement and COF length (both in the anteroposterior and lateral directions) was found to decrease as age increased. Also, when data was normalized by leg length, no significance was found in the different age groups when measuring the ratio values between COF and head displacement. Similar to the research previously mentioned that postural stability increases as age increases, the work by Sakaguchi et al. shows that there is a significant difference in that total body sway decreases throughout development (COF and head displacement are dependent on one another). Rather, as an individual ages, their head displacement decreases (becomes more stable) which ultimately leads to a decrease in COF displacement. It must be noted that the absence of somatosensory observation makes this particular study unique from those previously mentioned, but due to the aforementioned research stating that somatosensory integration reaches adult levels at a relatively young age (5 years in said studies), the exclusion of this variable can be understood.

Although the work done by Sakaguchi et al. appears to be a different form of methodology compared to previously mentioned studies, the dependent variables are essentially the same. Essentially, the main difference is that Sakaguchi uses a raw form of kinetic data while the Cumberworth and Hirabayashi studies use scored data from a test battery (the SOT) which is based on center of pressure displacement during the various conditions. It is also important to note that the Sakaguchi work is not considered to be dynamic posturography testing due to the absence of perturbations. Measuring postural stability during static balance creates a baseline measurement that can be built upon. For instance, with the knowledge of how an individual utilizes their sensory integration during static balance can build a framework for questions regarding performance under dynamic conditions.

If dynamic posturography and kinetics in relation to balance make a single point, it is that human maturation leads to further control and stability within the body. As previously stated, somatosensory awareness are developed at an early age and therefore vision is recognized as a more reliant source of maintaining balance during development.

Also, information that total body sway decreases with age can be correlated with the increase in muscle strength which will help to defend against perturbations. However, integrating this information with results from static balance assessment will continue to broaden the knowledge of postural stability.

Postural stability and sensory integration in typically developing children using the CTSIB.

Rather than measuring dynamic posturography, this study investigated the sensory function during static balance with the use of a modified version of the testing instrument called the Clinical Test of Sensory Organization and Balance (CTSIB). The original test was developed by Shumway-Cook & Horak (1986) with the intent to measure equilibrium strategies while a subject stood on an unstable surface (a foam cushion). Within the original test design, there are six conditions that aim to create environmental variations that will assist in evaluating postural control. Conditions 1 and 4 ask the participant to stand quietly on a force plate, with their eyes open, for 30 sec.; whereas conditions 2-3 and 5-6 impair the vision of the participant (with the use of a blind fold during 2 and 3 and a visual restricting dome during 5 and 6) in order to test the vestibular function. The visual restricting dome is used for the purpose of not completely eliminating vision, but rather allowing a degree of peripheral vision to act as a sensory function in assistance with postural stability. Postural sway velocity is measured during each trial and is considered to be the main dependent measure. This measure is calculated by tracking the displacement of the participant’s center of mass (COM). The displacement of the COM is measured over the time of the trial which results in the sway velocity.

Past research has established the reliability and validity of the CTSIB (Crow et al., 1992, Deitz et al., 1991) and has led to the increased credibility of the assessment tool. Due to the short testing trials and simplicity of the equipment, the test is ideal for assessing children of various developmental levels and abilities. With this said, more recent studies have used modified versions of the original that continue to produce similar results.

Recently, Hsu et al (2009) designed a study that sought to discover the tests reliability and validity when the original version was modified. The difference in the work done by Hsu et al. as compared to the traditional version of the CTSIB, is that only 4 different conditions are tested. The visually restricting dome was excluded from this modified edition and therefore the participant either had full or no vision. This form of the assessment has been termed the *modified* CTSIB and has become a popular edition due to its even further brevity. The study by Hsu et al. included 215 typical children and ranged from 3 to 12 years of age. Results from this study gave further support for younger children relying on vision as a sensory essential during equilibrium in later ages of development. As other research has shown, Hsu et al. displayed that somatosensory reliance reaches adult levels at 3 years, while visual processing does not fully develop until later childhood (12 years in this instance). While the somatosensory development level mirrored the finding of previously mentioned studies, the achievement of fully developed visual sensory integration was earlier than previous findings. This can be explained by the difference in the testing instruments in that one is dynamically based (SOT) while the other is static (modified CTSIB). Thus, in static balance conditions, somatosensory development is similar to that found in dynamic conditions while the reliance on vision is greater in older ages in dynamic conditions.

The work in regard to the CTSIB not only established its credibility in assessing postural stability, but derivatives of the original version have expanded the clinical usability. It is interesting to note that the development of sensory integration strategies during dynamic and static testing have remained consistent with one another when comparing the aforementioned studies. Both assessment tools have been used to generate evidence that somatosensory feedback reaches adult levels at a relatively young age (3 years of age as previously mentioned). The only minor difference between the two assessments arise because visual feedback reaches full development at a younger age in static testing when compared to that of dynamic (12 and 16 years of age, respectively). Generally speaking, this can be easily understood due to the increased variability in dynamic testing environments and implies that as external perturbations are introduced, balance is disrupted. With a thorough understanding of sensory integration and postural control in typically developing children established, these assessments can now be interpreted when applied to children with different levels of development and those with disabilities, such as children in the autism spectrum.

Development of motor function and control in children with autism spectrum disorders.

The array of assessments previously mentioned demonstrates ways that motor proficiency and cognitive function can be measured in children. Analyses with these assessment tools have provided evidence that children with autism show motor performance delays. A review by Emck et al. (2009), an investigation of roughly 100 studies conducted between 1997 and 2007, revealed that children with autism “exhibit poor gross motor performance and problematic self perception of motor competence.” The compilation of these studies provides even a stronger background for understanding the intricacies of motor performance abilities in children with autism. An interesting point made by Emck et al. is that this population of children struggle with their personal belief that they will execute the task correctly. This line of thought can be created from the failure of several attempts, but explanation may also be found in the lack of appropriate mental preparation and rehearsal strategies usually seen during skill acquisition. However, such a concrete conclusion cannot be made from these points alone and a deeper understanding of the potential of these children must be gained. What are the underlying causes? What are the foundations of the issue(s) at hand?

Based on the research that existed in regard to motor control in children with autism, Jansiewicz et al. (20006) presumed that there was a void in the knowledge examining subtle motor signs in this population. Using the Physical and Neurological Exam for Subtle Signs (PANESS), researchers found that 4 of the PANESS variables provided definitive characteristics between the autism and control group. The four testing conditions in the PANESS are: 1.) Gait and Stations, 2.) Overflow, 3.) Dysrythmia, and

4.) Time movements. Each condition is designed to detect involuntary movements (subtle signs) within the larger gross motor skill. Administering this protocol to children with autism shows us that the deficiencies found in gross and fine motor skill assessments may be related to deficiencies within involuntary movements. Information regarding the delay found in the motor programming system leads to further implications that deficiencies may exist somewhere within static balance control. Such presumptions can be made due to the nature of static balance and its reliance on sensory integration techniques as previously mentioned in this review. With this said, relationships that exist between cognitive function and sensory integration during a static balance task will provide a foundation for inquiry regarding postural stability in children with autism.

Although autism is a complex condition that encompasses a variety of characteristics, it is important to understand how existing knowledge of these subsets within the condition can provide further information about the finer details of autism. In regard to these subsets, Nation et al. (2006) found there to be a relationship between children with developmental dyslexia and children with autism. Because both of these populations share similar characteristics, the nature of delays in children with dyslexia should be investigated in children with autism. In fact, it seems likely that research in regard to sensory integration and balance strategies in children with dyslexia will in fact provide further insight into deficits in those with autism. Soodley et al. (2005) inevitably found that children with developmental dyslexia have shown deficits in sensory integration skills, most notably during balance. Results from this study state that when children with developmental dyslexia (determined by prior diagnosis) attempted to balance on one foot during an “eyes-open” and “eyes-closed” condition (similar to that of the CTSIB protocol previously mentioned), a greater lack of balance became apparent when compared to the control group. Subjects were determined to be “less stable” by tracking their movement during a 10 sec trial with the use of a motion-tracking system. These results suggest that a similarity in sensory integration during balance may exist between children with developmental dyslexia and children with autism.

Balance strategies in children with autism

Dynamic balance strategies in children with autism have been researched by investigating the role of balance during their walking strides. Vernazza-Martin et al. (2005) designed a study investigating how gait and balance in children with autism varied when the goal of the task was changed. Balance was measured by “taking the standard deviation of head, shoulder and pelvis angles in respect to their mean orientation in the frontal and horizontal planes” while the child walked toward the pre-determine target. Results indicated that while equilibrium control was similar to that of typical children tested, the children with autism showed much more variability from trial to trial. The authors hypothesized that this occurs at the level of “locomotor spinal centres with an impairment of modulatory action (Grillner, 1975)” as well at the “level of basal ganglia involved in the spatial and temporal encoding of the movement (Brown, 1990).” The biological difference in brain structure that leads to deficits in equilibrium control offers a new piece to this puzzle. However, it should be noted that dynamic balance is much more complex when compared to static balance due to the environmental variables (inconsistencies, perturbations, etc.) that act on the body during the voluntary act of moving toward a target. Therefore, to further understand the role of sensory integration during balance, assessment during a static balance task would answer these questions more concretely.

Limitations are present in each of the aforementioned studies and raise questions about the information they provide to the understanding balance control. Experimental procedure in the Stoodley et al. research asked each participant to balance on one leg during an eyes-closed and eyes-open condition. While this is considered to be static balance, the unconventional nature of the action is difficult to translate into a typical quiet stance with both feet on the ground. The investigation of static balance strategies during a stance using both feet, rather than performing a skill (standing on one leg), would increase the validity when concerned with development progression. Also, while the results provided by Vernazza-Martin and coauthors provides insight to the biological structure of the brain and its relationship to balance strategies, the previously mentioned dramatic differences between static and dynamic balance create difficulties when attempting to relate knowledge about one condition to the other. Knowing these limitations, experimental procedures can be structured and manipulated with the intent to define sensory integration strategies during static balance with the use of a validated and reliable assessment protocol, such as the CTSIB.

Sensory integration and postural stability in children with autism.

The methodology of understanding sensory integration techniques during various static balance conditions holds true for children with autism just as it has shown to be valid in children with typical development. Similar to the assessment of typically developing children, there are a variety of assessments to choose from that each provide their own unique data. Prior to the use of current and up-to-date systems, Kohen-Raz et al. (1992) used a method referred to as "tetra-ataxiametry" to research postural control in this population. The procedure was designed into four different categories and created a cumbersome testing process for the participants and test administers. Although this methodology is currently out-of-date, results demonstrated that children with autism had lower postural control when compared to the control group. A more modern study by Minshew et al. (2004) tested postural control in 79 individuals with autism and 61 healthy individuals with the use of the EquiTest. The dynamic posturography testing the subjects with autism showed deficits in postural stability when compared to the typically developed population. A unique characteristic about the Minshew study is that the age of the subject population ranged from 5 to 52. With the use of this age range, the authors were able to show that while the typically developing population reached adult level sensory integration during childhood, the autistic population never reached such levels. These data continue to support the idea that rehabilitation methodologies not only need to be focused on developing children, but should be designed with lifespan development in mind. The next phase in understanding postural stability in children with autism is to examine the development of children and its relationship to static balance with the intent of producing more specific and explanatory data.

During a quiet and static stance, the movement of the body happens on a minimal scale. As technology advancements are made, new techniques are created that improve the understanding of these discrete changes. For instance, center of pressure (COP) is a commonly used method that creates what are referred to as “tracing plots” or stabilograms when researching static balance. In a study by Fournier et al. (2010), this method was used to investigate the decreased static postural control in children with autism. Rather than using an existing assessment tool, authors decided to rely on this fundamental kinetic technique. During the static trials of their study, movement of the COP was measured in 2 different directions and an area (mediolateral, anteroposterior, and sway) in 13 children with autism spectrum disorders as well as 12 typically developing children. In regard to the sway area of the COP in subjects, results from the study stated that as typically developing children aged, sway area decreased; whereas in children with autism, the sway are remained unchanged throughout development. These results are important to note due to the similarity of the “sway” variable found in this methodology and in the CTSIB. However, the design of the Fournier et al. study focused only on postural stability without including the role of sensory integration and also had a relatively low sample size.

In order to accurately define the relationship between sensory integration and postural stability, consideration of visual, vestibular and somatosensory variables must be taken into account. Research protocol such as that found in the CTSIB, designed to focus on these variables, utilizes techniques such as occluding vision and providing unstable surfaces. Although the exact CTSIB protocol was not used, Molloy et al. (2003) designed and used a similar method called AccuSway. There are four testing conditions in this method: eyes-open on a firm surface, eye-closed on a firm surface, eyes-open on a foam surface and eyes-closed on a foam surface. Each of these conditions mirrors one used in the CTSIB. Molloy and coauthors analyzed the data by taking the median and range "sway area" (measured from the stabilograms) of each subject and comparing results from the two groups. Children in the autism group were found to be much more reliant on visual strategies when compared to the typically developed group. This was determined by measuring the differences in sway area from one condition to the other. Therefore, a larger the difference in sway indicates that it becomes more challenging for the individual to make the needed sensory integration adaptations to the environmental conditions (e.g. lack of vision). This information continues to support the idea that children with autism show a deficit in postural stability, but this particular study provides more knowledge regarding the deficit's correlation with sensory integration. Even though the work by Molloy et al. had a limiting factor of a small sample size (8 children with autism and 8 typically developed), the results provided a starting point to designing a study that would produce even more valid and reliable results.

Chapter Three

Methodology

Data for this study came from two sources. Data on typically developing children were obtained experimentally. We compared to an existing database (provided by NeuroSensory Centers of America) consisting of 79 children diagnosed with autism. Experimental procedures for this study were modeled after the procedures used to obtain the archived data set. Participants completed the Clinical Test of Sensory Interaction and Balance in an assessment of their responses to altered sensory conditions during a postural task. During each of these conditions, postural stability, as defined by *postural sway*, was used as the dependent measure. Each assessment was completed during static stance and all participants completed the same number of trials.

Experimental Design

The study design was quasi-experimental. Postural control was evaluated as a function of age and diagnostic group (children considered neurotypical (those without autism) and children with autism diagnosis). Group differences were measured by observing postural sway in each testing condition between the control and experimental groups within each age group.

Participants

Participants in this study, matched by gender, were assigned to one of three separate groups according to age: 3 year olds, 4 year olds and 5 year olds. The total population of typically developing children consisted of 32 participants with 16 males and 16 females. Within each gender group, age representation was mirrored so that with each gender group consisted of 5 three year olds, 5 four year olds and 6 five year olds. The selection criterion for the experimental group was based on an attempt to match age and gender with a sample of the archived data set.

This archived data set consisted of 79 total children all of whom had been diagnosed with autism. The total population included 21 females (five 3- year olds, seven 4- year olds and nine 5- year olds) and 58 males (six 3- year olds, seventeen 4- year olds and thirty-three 5- year olds), as can be seen in Table 1.

Table 1: Descriptive characteristics of the data (autistic population data provided by NeuroSensory Centers of America).

	Neurotypical (n = 32)		Autism (n = 79)	
	Male (16)	Female (16)	Male (58)	Female (21)
3 yrs	5	5	6	5
4 yrs	5	5	17	7
5 yrs	6	6	35	9

Typically developing children were recruited from a local day care facility. Parents of participants in the experimental group provided consent prior to participation in the study.

Instrumentation

Cognitive function was assessed byuse of the Kaufman Brief Intelligence Test, Second Edition (KBIT-2) (Kaufman & Kaufman, 2004). Decrements in motor performance are correlated with low IQ scores (reference), thus the KBIT-2 was used as a screening tool. The test employs both verbal and non-verbal components validated for use with individuals between 4 and 90 years of age. The IQ composite portion of the test has been reported to be highly reliable (0.93) with strong test-retest reliability as well (0.93 ;Kaufman & Kaufman, 2004). Homack & Reynolds (2007) replicated the reliability of this cognitive assessment.

Brevity of the assessment leads to an assessment time of approximately 10 to 15 min. An assessment of cognitive development was made by comparing the obtained IQ composite score against the percentile rankings of the standardization sample. Administration of the test was stopped after the participant reached an IQ composite score of 85, which is the lower end “normal” cutoff. One of 33 participants failed to reach this benchmark and this child was excluded from the experimental group. A final total of 32 neurotypical children participated in the study.

Postural stability data collection was conducted with the use of a NeuroCom system and force plate (Very Simple Rehabilitation (VSR) [Computer software].

Clackamas, OR: NeuroCom International, Inc.) and data collection was managed by Sensory-View software (Stewart, K. (2003). Sensory-View [Computer Software]. Austin, TX: Sensory View of America, Inc.). The modified version of the CTSIB was used. The modified version encompasses four separate testing conditions which are (a) eyes-open on firm surface, (b) eyes-closed on firm surface, (c) eyes-open on foam surface, and (d) eyes-closed on foam surface. Three 10 s trials were collected within each of the four conditions. During the eyes-open (EO) condition, the participant was asked to maintain eye contact with a predetermined point straight ahead of them. This was done to avoid head movement. During the eyes-closed condition (EC), the participants were asked to close their eyes voluntarily rather than be assisted with the use of a blindfold. This was done to mirror the data collection process used for the archived data set. The foam pad used during two of the testing conditions was 3 inches in thickness. Each condition (eyes-open on foam (EOF) and eyes-closed on foam (ECF)) was performed while the participant stood in an erect posture with their arms across their chest. Foot position was standardized by the use of markings on the force plate that mark the position of the heel and large toe.

Average sway velocity was calculated by taking the displacement (measured in cm) of the COP and dividing it by 10 s (the length of the trial). Data was collected at a sampling rate of 100 Hz. An example of the provided output can be seen in Appendix A. This was done for each trial and averaged in order to provide one value for each condition.

Procedures

Each participant was individually assessed in a separate room to avoid external distractions and was told they were going to play “balancing games” (postural sway testing) and “picture/word games” (K-BIT2 assessment). These alternative descriptions to the assessments were used to help the child understand what was being done in a non-threatening description.

To begin the assessment, and verify the inclusion criteria of typical cognitive function, the K-BIT2 was administered to each child. The assessment is designed to evaluate verbal and non-verbal performance which is compared to a normative data set. The verbal section of the assessment asked the child to verbalize their response when asked a series of questions, where the nonverbal portion of the assessments asks the child to point to a picture in response to the question that is given. Each item on the assessment was scored with either a “1” (correct) or a “0” (incorrect). Once four consecutive items were answered incorrectly, the section of the test was stopped. The sum of the correct responses (values of “1”) were taken and recorded in the summary sheet of the assessment. After all summations were taken from the three different test sections, tables provided by the testing instrument allowed the researcher to determine the percentile ranking for the child. Analysis regarding the child’s cognitive ability determined by the K-BIT2 was not discussed directly with the child at the completion of the assessment, however, this information was provided for the child’s family. If the child did not achieve a standardized IQ composite score of at least 85 (determined through the calculation of the individual’s verbal/nonverbal scores and then compared to a chart that provides the “standardized score”), the data collected were excluded from the final analysis.

At the completion of the cognitive analysis, testing proceeded with the postural stability assessment. Each child was introduced to the various pieces of equipment (the force plate, computer and foam pad) and asked if they had any questions. To ensure that a certain level of comfort was achieved during the testing trials, each child was allowed to “test” the foam pad and become familiar with it. This included the child touching, standing and/or sitting on the pad.

During all conditions of the assessment, the child stood erect with arms crossed over their chest while facing forward. Conditions included standing on the force plate with the eyes open (EO) and eyes closed (EC) in addition to standing on the foam pad with the eyes open (EOF) and eyes closed (ECF). Within each condition, three 10 s trials were performed consecutively without rest. The experimental procedure is outlined in Appendix B.

Analysis

Data were statistically analyzed by way of a 2 (diagnostic group) x 2 (gender) x 3 (age) x 4 (balance condition) analysis of variance (ANOVA) with repeated measures. Sway velocity was the dependent variable. The independent variables in the study were gender, age (3, 4 and 5 years) and diagnostic group (“autism” or “neurotypical”). There is no prediction for a gender main effect as there is little evidence in the developmental literature that there is any distinction in gender for postural control in this age group. An age main effect is expected as motor performance is correlated with age. Finally, a group main effect is expected as children with autism have been shown to be delayed in the development of motor skills.

Post hoc testing using a Tukey adjustment was performed when univariate significance was found. For all analyses, a *p-value* of .05 was used to determine the significance in a comparison.

Chapter Four

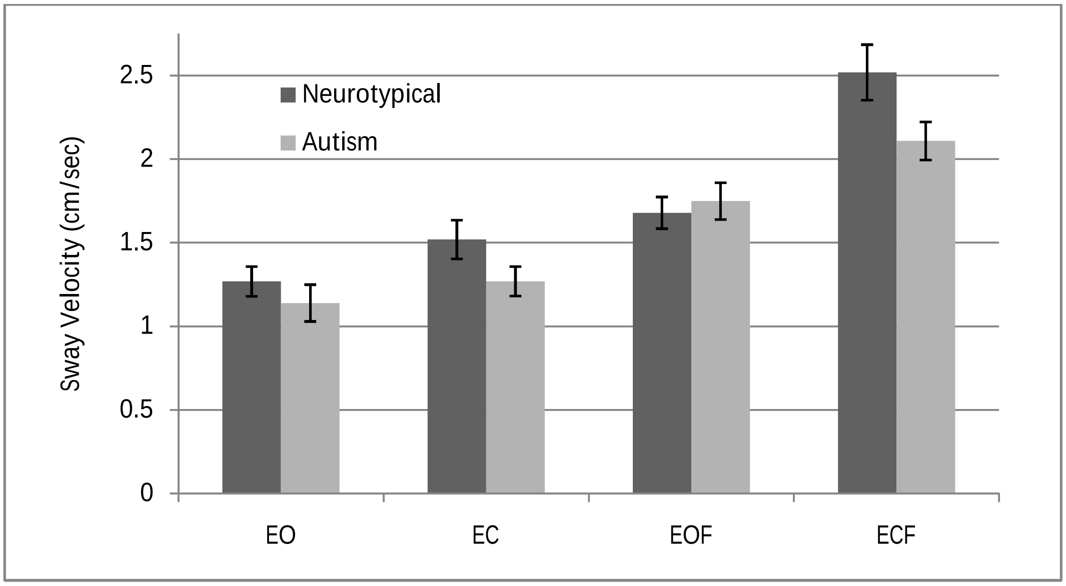
Results

The purpose of this study was to determine if differences in standing postural control exist between children with a diagnosis of autism and children with no diagnosis (neurotypical). In this study, we examined hypotheses related to age (3-5 year olds) and group (autism diagnosis or neurotypical). We hypothesized that the children with autism, independent of gender, would display higher sway velocities than those in the neurotypical group.

A 2 (diagnostic group) x 2 (gender) x 3 (age) x 4 (balance condition) ANOVA (with repeated measures on the last factor) was performed. Initial univariate analysis of gender showed no main effect ($p > .05$). The next step was to collapse across gender and test the hypotheses for developmental trend (age), diagnostic condition, and balance control. Subsequently, a 2 (group) x 3 (age) x 4 (balance condition) ANVOA with repeated measures was performed.

Results show that there was no main effect for diagnostic group (F (1, 105) = 1.28, $p = .261$). Children with autism did not differ from typically-developing children in sway velocity. Figure 1 shows group performance (collapsed across age) for each of the four sensory conditions.

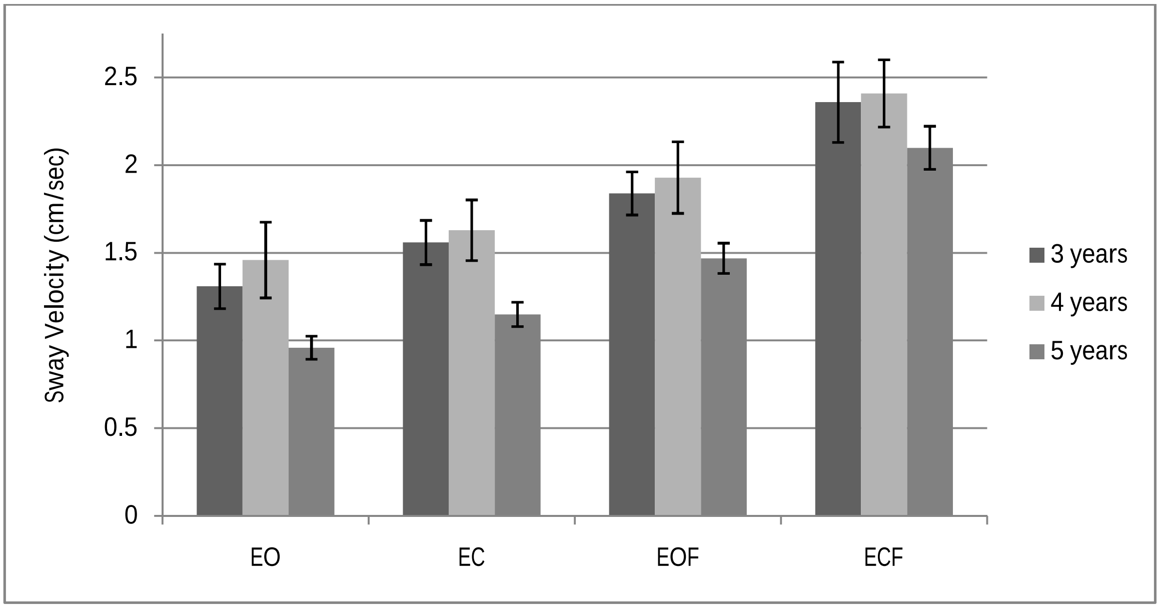
Figure 1: Average sway velocities for Neurotypical and Autism groups (collapsed across Age) across all balance conditions.



* EO (eyes-open), EC (eyes-closed), EOF (eye-open on foam), ECF (eyes-closed on foam)

There was a significant main effect for Age (F (2, 105) = 7.026, $p < .05$). Post hoc testing revealed that children in the 4 year old group had significantly higher sway velocities when compared to the 5 year old group, however, there was no significance found in regard to the 3 year olds (Figure 2). Assessment conditions (EO, EC, EOF and ECF) also displayed a significant main effect (F (2, 219) = 53.32, $p < .05$). Post hoc testing for conditions revealed that all conditions were significantly different from one another as average sway velocity increased in each condition from EO to ECF.

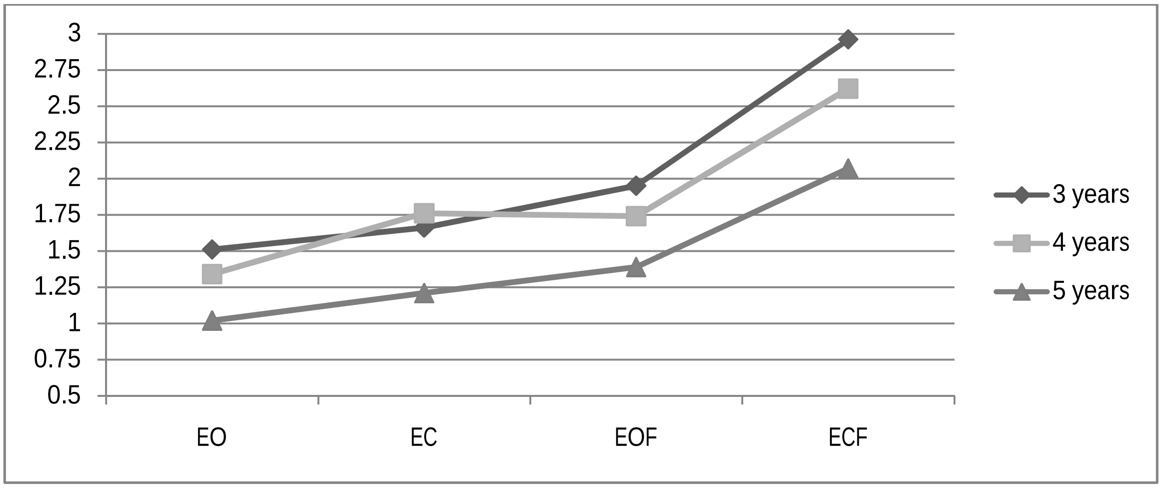
Figure 2: Average sway velocities for each age group across conditions.



*EO (eyes-open), EC (eyes-closed), EOF (eyes-open on foam), ECF (eyes-closed on foam)

Further analysis of the difference between age groups was done by examining each diagnostic group individually and examining age differences across the four sensory conditions. For the neurotypical group, there was no significant within-subjects effect ($F = 1.06$, $p > .05$) indicating that no differences existed in each age group across each of the conditions. However, there was a significant between-subjects effect ($F = 3.60$, $p < .05$) indicating that each age group differed from one another across each of the conditions (Figure 3).

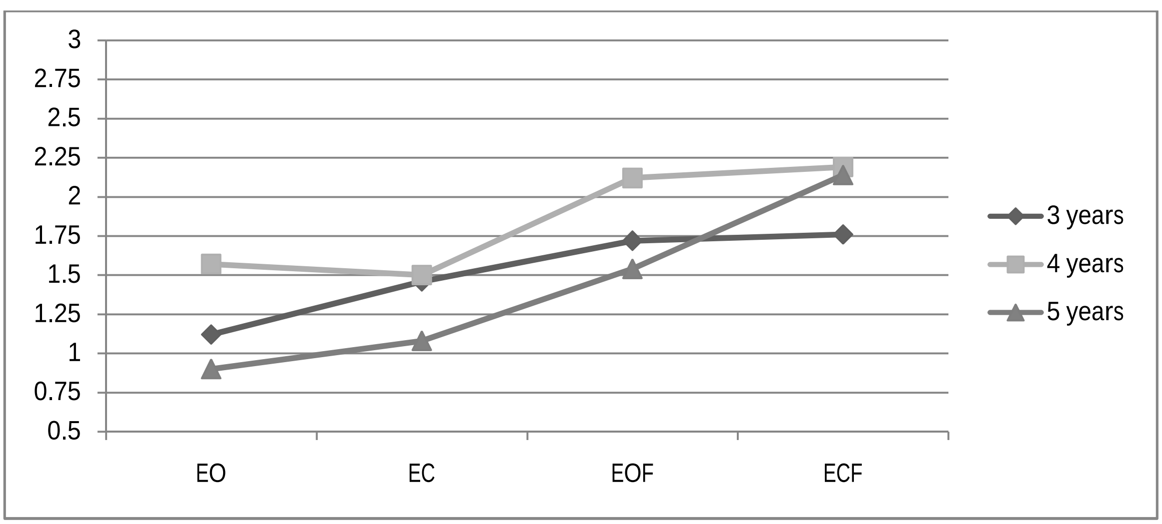
Figure 3: Neurotypical group: Average sway velocities for each sensory condition.



*EO (eyes-open), EC (eyes-closed), EOF (eyes-open on foam), ECF (eyes-closed on foam)

The autism group failed to show a significant within-subject effect ($F = 2.36$, $p = .054$) and no significant between-subject effect ($F = 2.60$, $p > .05$). Each age group varied across each of the conditions, but the age groups do not differ from one another (Figure 4).

Figure 4: Autism group: Average sway velocities for each sensory condition.



*EO (eyes-open), EC (eyes-closed), EOF (eyes-open on foam), ECF (eyes-closed on foam)

Chapter Five

Discussion

The results from this study show age-related changes in emerging postural control. Five year olds perform better than younger children across a variety of sensory conditions. The study results did not, however, support our expectation of significant delay in balance control in children with autism. It was only by looking at the within-group differences of age by condition for the autism group that we see a trend toward emerging developmental delay.

Findings from this study failed to reveal differences in sway velocity between the diagnostic groups tested. This does not support the expectations derived from the literature, which were that typical children would display more postural stability (i.e. lower sway velocity) than the children with autism. Based on the existing literature, we expected that age would lead to a regular increase in postural stability in typical children with little to no improvement occurring in the autism sample. The results from this study support the predictions for the typical group but not the atypical group as typically developing children displayed a progressive developmental pattern while the children with autism did not.

Expected results from this study were formulated by investigating past research that sought to explain the developmental process of sensory integration. For instance, Shumway-Cook (1986), Hirabayashi et al. (1995) and Cumberworth et al. (2007), although using variations in balance assessment, each drew the same conclusion: children develop adult level somatosensory feedback at an age younger than 5 years. Each author varied on their conclusions made on visual and vestibular development, but there was a consensus that visual sensory feedback reaches adult levels around the age of 7 years while vestibular feedback matures during adolescence. As the balance conditions become more challenging, dependence upon the sensory systems changes. In the eyes-closed condition, postural control is dependent upon somatosensory and vestibular system inputs. The on-foam conditions (EOF and ECF) challenge the somatosensory system and create greater reliance upon the vestibular system. Independent of age, then, control of postural sway becomes more challenging across the four tests (EO, EC, EOF, and ECF). Children with autism, however, are often described as having poor sensorimotor integration. Thus we expected to find the children with autism lagging behind their age-matched peers in this assessment of balance control.

The findings of this study are contradictory to previous research. Past research has been consistent in stating that children with autism clearly exhibit a deficit in postural stability when compared to those who are typically developing (Minshew, 2004; Malloy, 2003). Although not statistically significant, the autism group recorded lower sway velocities in all but one of the conditions.

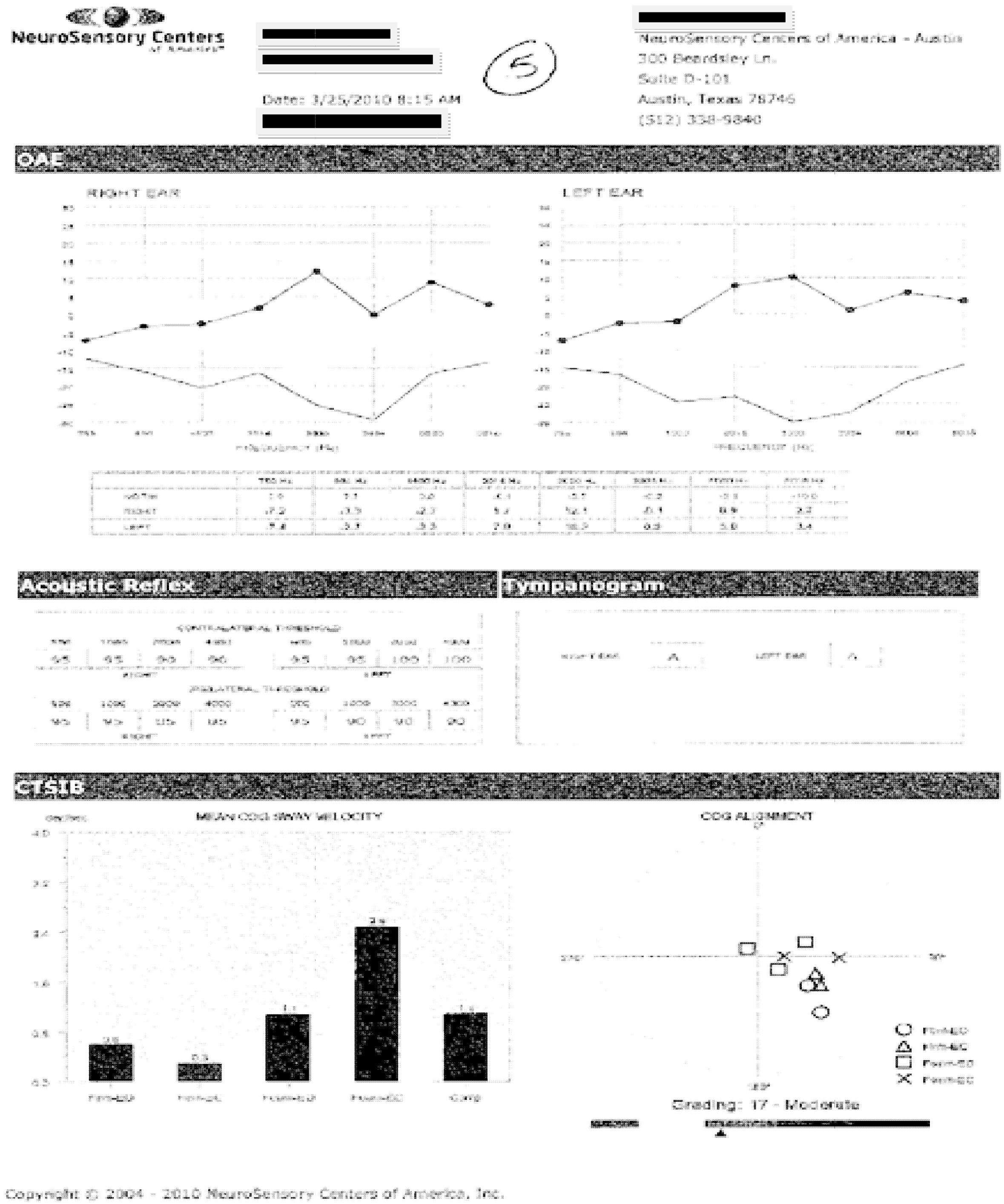
When focus is placed on the differences between age groups, one cannot help but notice the differences and similarities that exist when compared to previous findings. The differences found between 4 and 5 year olds mirrors that of previous research and suggest that a notable improvement in postural stability is made in that time. Yet the children in the 3 year old age group recording lower sway velocities than the 4 year olds (but still higher than 5 year olds) in all but one condition. The conclusion can be drawn that more variability in postural stability is occurring at the age of 4. However, this increased variability may also be explained by the findings of Shumway-Cook & Woollacott (1985) as they noted a “reorganization” of postural control in between the ages 5 to 7. The increased variability observed in the children during the age of 4 is well worth mentioning and suggests that further dedication be given to understanding the specifics of sensory integration at this age. When these results were further analyzed and split between diagnostic groups, clarity in this relationship was revealed. Children in the neurotypical group displayed a typical developmental progression while children in the autistic group displayed a very inconsistent developmental pattern.

Through the analysis of the data collected in this study and comparing the produced results to that of previous work, two major observations arise from this study. First, neurotypical children showed a typical developmental trend across conditions while children with autism displayed inconsistent developmental progress. Second, no difference was found between diagnostic groups. In order to further understand the differences in developmental trends between these two groups, further research may specify the definition of age (i.e. months instead of years) for children with autism in order to determine exactly where changes are occurring. Alternatively, a longitudinal study may help to identify where in the developmental trajectory children with autism begin to significantly diverge from their non-diagnosed peers. In regard to the differences in developmental progress between the two groups, further research could replicate the work by Minshew (2003) with the inclusion of these younger age groups. Data from this study suggest that children with autism follow a typical developmental trajectory in the early years, but begin to slow in balance improvements by the age of 5 years. Therefore, extending this design past the age of 5 years would examine this apparent divergence in developmental trajectory.

Findings from this research help us to further understand the intricacies that exist within development and especially in atypical populations. Evidence from this study adds to the literature that children with autism display inconsistent developmental patterns that are unpredictable. Thus, this level of uncertainty in how a child with autism develops translates directly into the delay in their activity levels and maturation due to the various set-backs that they are faced with. It is imperative that these delays and inconsistencies be completely understood so these children can experience a life of physical activity and leisure. It cannot be denied that advancements are being made in the understanding of these children, but a deeper knowledge in the crucial integration of the sensory systems will allow for the evolution of activity programs to invigorate these children rather than disable them further.

Appendix

Appendix A



Appendix B

Condition	Trials Performed	Trial Duration	Description
1	3	10 sec.	Stand on the floor with arms placed across chest and hand touching shoulders. Feet together with ankles touching while **eyes are open**.
2	3	10 sec.	Stand on the floor with arms placed across chest and hands touching shoulders. Feet together with ankles touching while **eyes are closed**.
3	3	10 sec.	Stand on a 3 inch thick high density foam cushion with arms across chest and hands touching shoulders. Feet together with ankles touching while the **eyes are open**.
4	3	10 sec.	Stand on a 3 inch thick high density foam cushion with arms across chest and hands touching shoulders. Feet together with ankles touching while the **eyes are closed.**

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Vita

Christopher John Stanfill was born in Salt Lake City, Utah. Spending the majority of his life in Phoenix, Arizona, he graduated from Desert Vista High School in 2003. After high school graduation, he was given the opportunity to play collegiate golf at the University of North Texas in Denton where he graduated cum laude with a Bachelor of Science degree in Kinesiology in 2007. Taking one semester off from academics and working in the sales industry, he returned to education by entering the Movement Science program at the University of Texas at Austin in January 2008.

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