THE EFFECTS OF SENSORY PROCESSING DISORDER IN RELATION TO PRAXIS SKILLS IN YOUNG CHILDREN WITH LEARNING DISABILITIES AND/OR ATTENTION DISORDERS

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Submitted in partial fulfillment of the

requirements for Departmental Honors in

the Department of Kinesiology

Texas Christian University

Fort Worth, Texas

May 6th, 2019

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ABSTRACT

The purpose of this study was to explore if children with learning disabilities (LD) and/or attention disorders experienced praxis deficits due to sensory processing disorder (SPD). Fourteen participants (ages 7-13, 10 Male, 4 Female) with documented LD and/or ADHD were recruited from Starpoint School. Ten participants had both a LD and ADHD. Participants completed a praxis assessment of gross and fine motor skills. A parent/guardian of each participant completed a Winnie Dunn Sensory Profile Questionnaire to assess sensory processing patterns. Participants' overall gross motor mean scores were higher compared to fine motor ($3.62 \pm .27$, $3.54 \pm .07$). The Winnie Dunn results indicated that participants with comorbid disabilities most commonly scored between +1SD and +2 SD, and above +2 SD in the Visual, Movement, Oral Sensitivity, Conduct, Social Emotional, and Attentional categories and Seeking and Sensitivity quadrants. Statistically significant correlations were found at both alpha levels of 0.05 and 0.01 between the self-regulation praxis skill and various sensory categories/quadrants (i.e. seeking quadrant). It can be suggested that a child with comorbid LD and ADHD may experience decreased or increased sensitivity thresholds that decrease their ability to execute successful praxis, more specifically self-regulation fine motor tasks. Decreased praxis abilities exacerbate existing symptoms leading to dysfunction at school, home, and in the community.

ACKNOWLEDGEMENTS

I first want to thank the Starpoint School, specifically Dr. Marylin Tolbert and Dr. Amanda Young, for allowing me to conduct my research on campus and helping me through the recruitment process. I also want to thank the parents and students for participating in this study.

I want to thank my family, my parents Mark and Pamela Aguilar and my sister Brooke Aguilar, for their constant love and support. They have always encouraged me to dream big and pursue what I am passionate about. Without the chance to attend TCU, I truly believe I would not have been given the opportunities I have been able to seize at this university.

I also want to thank Dr. Stephanie Jevas and Dr. Wendy Williams for taking the time to be a part of my research committee. It means so much to have such accomplished individuals supporting my research goals.

Lastly, thank you Dr. Esposito for not only helping me decide to attend TCU in the first place, but always looking out for me as an advisor, professor, mentor, and kind human being. I appreciate all the brainstorming sessions and research meetings we've had in order to bring a topic I am passionate about to life. Being able to attend the AOTA 2019 Conference as an undergraduate researcher will be an experience I will never forget. I have always felt lucky knowing I had a mentor who would go to bat for me and genuinely wants to see me succeed in my education, career, and life paths. I sincerely would not have been able to complete this research without your encouragement or guidance, nor would I be able to have gotten into such an amazing OT graduate program. Thank you!

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INTRODUCTION

Sensory Processing

Sensory processing is defined as the ability of the central nervous system to assimilate, process and organize appropriate responses to information (Shimizu, Bueno, & Miranda, 2014). It allows an individual to integrate sensory input and adapt with responses based on the environment, permitting meaningful life engagement (Pfeiffer, Daly, Nicholls & Gullo, 2015). The four main brain structures involved in sensory processing are the brain stem, the cerebellum, the diencephalon, and the cerebrum (Kranowitz, 2005). In addition to these, the sensory and motor cortexes are also crucial to sensory processing success. In the 1960s, Dr. A Jean Ayres, a psychologist and occupational therapist, introduced the sensory integration theory which states that “in order to determine how an individual interacts with their environment, the process of organizing sensation from their body and environment must be observed” (Roley, Mailloux, Miller-Kuhaneck & Glennon, 2007). Sensory processing can be broken down into two subcategories: modulation and discrimination. Sensory modulation is defined as the ability to grade responses to incoming sensory information and produce behaviors that are neither overreactive nor underreactive to the situation (Bodison et al, 2008). Sensory discrimination is defined as the ability to accurately perceive and utilize a sensation in a refined way to produce adaptive functional behaviors (Bodison et al, 2008).

Sensory Processing Disorder

Although not currently recognized by the DSM-V, Sensory Processing Disorder (SPD) is defined as a neurophysiological condition in which sensory information either from one’s own body or the environment is poorly detected, modulated, or interpreted, and/or to which atypical responses are observed (Miller, Coll & Schoen, 2007). SPD can be identified and categorized by an occupational therapist with specific training through standardized testing, clinical observations and/or screening and additional evaluations from a multi-disciplinary team (STAR Institute, 2017). An individual's sensory processing problems can be considered a *disorder* if the sensory issues experienced cause dysfunction in daily life that subsequently lead to a decline in quality of life (Miller et al, 2007). SPD occurs on a continuum, with individuals experiencing mild dysfunction on one end, and those with comorbid diagnoses experiencing severe sensory processing issues on the other end. Individuals with SPD in terms of sensory modulation are unable to regulate their behavior in response to stimuli. This could take on many forms, such as under-responsivity, over-responsivity, sensory seeking or sensory avoiding. On the other hand, SPD in relation to sensory discrimination lies within brain activity. Dr. A Jean Ayres reported that discrimination "leads to perception, conceptualization, and action in order to produce functional body scheme, smooth accurate movement, bilateral skills, visual perception and praxis" (Ayres, 1964). Depending on the sensory system affected, lack of appropriate discrimination will not allow the individual to engage in purposeful tasks or facilitate learning. Additionally, Dr. A Jean Ayres advocated the idea that learning occurs when a person has the ability to receive accurate sensory information, process it, use it to organize behaviors, and adapt responses (Matsushima & Kato, 2013). Aside from modulation and discrimination, individuals may also experience sensory-based motor problems where they have difficulty conceiving an action to do, planning how to organize their body, and carrying out an action plan. Lastly, inefficient sensory processing can lead to associated regulatory and behavioral problems such as social emotional regulation and attention abilities.

To date, the exact cause or causes of SPD are unknown. However, researchers speculate a number of possible factors such as genetic or hereditary predisposition, prenatal and/or postnatal circumstances, prematurity, and birth trauma (Kranowitz, 2005). The prevalence of SPD has ranged from 5% to 10% for children without disabilities and 40% to 88% for children with various disabilities (Ahn, Miller, Milberger, & McIntosh, 2004). Although SPD can be a stand-alone disorder, it often coexists with and complicates other problems. For example, if a child has autism, he may also have over-responsivity to touch. The sensory problem does not cause autism, but it exacerbates the issues. Researchers at UC San Francisco discovered through the use of an advanced form of MRI called diffusion tensor imaging (DTI) that children affected by SPD have quantifiable differences in brain structure (Bunim, 2013). The imaging displayed abnormal white matter tracts in the SPD subjects primarily in the back of the brain that serves the auditory, visual and somatosensory systems involved in sensory processing. This indicates that SPD may be neuroanatomically distinct from ADHD or autism spectrum disorder, which typically shows more frontal anterior white matter tracts. In addition, children who display sensory processing issues are at an increased risk for poor social skills, low self- confidence and self-esteem (Parham & Mailloux, 2001). Children who struggle academically without a diagnosis and children who struggle academically with a diagnosis such as autism spectrum disorder, learning disability, and ADHD, are examples of populations that are normally referred for sensory integration therapy (AOTA, 2008). This demonstrates the noteworthiness of this study as finding common denominators between comorbid issues is key. Occupational therapists have attempted to combat SPD by using techniques based on the sensory integration theory introduced by Dr. A. Jean Ayres.

Praxis and Motor Development

Praxis is defined as the planning, execution, and sequencing of movements (Parham, 1998). Praxis, often thought of as motor planning, includes both skills for movement as well as the cognition to organize tasks. An individual carries out specific motor movements for a purpose and can learn new motor activities based on ones already experienced (Listen and Learn Centre, 2014). Praxis is a learned skill and is based partly on sensory processing and partly on conscious thought. A child develops this over time through sensory exposure and exploration of learning. Therefore, dyspraxia may cause an individual to have difficulty sequencing and carrying out several step motor plans that involve several steps. Children with dyspraxia may have normal intelligence and muscular function, but there is a gap between their neurological functioning and their muscle physiology due to inaccurate information being received, thus leading the child to an incorrect or delayed movement (Kranowitz, 2005).

A characteristic of early childhood is the development of fundamental motor skills that include locomotion such as running, galloping, skipping, hopping, sliding, leaping, etc. In addition, object manipulation skills develop including throwing, catching, bouncing, kicking, striking, and rolling (Morgan, Barnett, Cliff, Okely, Scott, Cohen & Lubans, 2013). Movements can be subdivided into gross and fine motor skills. Gross motor skills involve movement of large muscles like arms, legs, and torso. These skills impact balance and coordination. Fine motor skills are movements involving the small muscles in our hands, wrists, and fingers (Skowroński, Winnicki, Bednarczuk, Rutkowska, & Rekowski, 2018).

Attention Disorders/Learning Disabilities

Currently, the DSM-5 states that five percent of children experience one of the three subtypes of Attention Deficit/Hyperactivity Disorder, or ADHD (American Psychiatric Association, 2013). Attention-deficit/hyperactivity disorder is one of the most common neurobiological disorders in children that is often accompanied by comorbid problems (Wilens & Spencer, 2013). The population affected by ADHD is heterogeneous and the degree of symptoms vary significantly. Individuals with ADHD demonstrate a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development (American Psychiatric Association, 2013). Based on a person's symptoms, ADHD may present as one of three types: predominantly inattentive, predominately hyperactive-impulsive, or combined presentation (American Psychiatric Association, 2013). In addition, ADHD is also considered a developmental disability, therefore professionals are able to hypothesize that inconsistencies are likely to occur among aspects of a child's development if they develop ADHD. Areas of development may include motor skills, social skills, daily living skills, communication, among others. Delays are recognized if there are significant delays in two or more of these areas, which allows for the integration of early intervention programs and school readiness initiatives (Wilens et al, 2013).

Children with ADHD often present with over-responsivity in tactile situations as indicated by standardized tests filled out by their parents or guardians. These disproportioned reactions, referred to as dysfunction or deficit, possibly relates to their distractibility or inattention. Thus, there is some confusion in the literature about whether or not typical symptoms of ADHD are actually symptoms of SPD. In a study of preschool children, children with greater sensory deficits were more likely to display higher levels of hyperactivity behavior (Yochman, Parush, & Ornoy, 2004). In a study of six to ten-year-old boys, boys with ADHD had more sensory processing difficulties than boys without ADHD, but no significant differences were found in the pattern of sensory processing problems between subtype of ADHD (Engel-Yeger & Ziv-On, 2011).

In a 2015 study by Pfeiffer, Daly, Nicholls and Gullo, it was investigated whether children with ADHD were at a greater risk than children without ADHD for problems with sensory processing and if certain sensory systems were more closely associated with the core symptoms of ADHD (inattention and hyperactivity/impulsivity). The results of this study indicate that children with ADHD demonstrated significantly more sensory processing dysfunction than children without ADHD in the areas of visual, auditory, tactile, proprioceptive, vestibular, social participation, and praxis. Findings also demonstrated higher levels of hyperactivity/impulsivity in children with ADHD were highly related to poorer social participation and praxis functioning.

Children with ADHD may not receive and process sensory information properly and consequently, have difficulty producing adaptive responses at school, at home, and in social settings. This may affect motor and functional performance as well as behavioral aspects of children's, including a child's ability to learn, to organize and to maintain appropriate activity levels. (Shimizu, Bueno & Miranda, 2014).

Although symptoms of sensory processing disorders can overlap with features of ADHD, a dissociation between ADHD and SPD has been suggested from experimental data. In a sample of typically developing children who participated in the standardization of the Leiter International Performance Scale-Revised, 181 children had symptoms of either sensory or attention impairments, or both. Children who had symptoms of impaired attention (56%) also demonstrated symptoms of impaired sensory processing. It is notable that approximately the same percentage of children within the sample of sensory and/or attention impairments and the sample of attention deficits had symptoms of dysfunction, suggesting that ADHD and SPD are distinct conditions (Roid & Miller, 1997).

According to the AACAP (2013), one in ten children suffer from a learning disorder. Children with learning disabilities (LD) are a heterogenous population due to the different underlying neuropsychological deficits. The two subtypes of LD are reading disabilities and deficits in problem solving, psychomotor skills, and arithmetic difficulties (Di Brina, Averna, Rampoldi, Rossetti, & Penge, 2018). The association of LD with motor skills, especially coordination is common. At least 50% of children with LD have a comorbid developmental coordination disorder, or dyspraxia (Di Brina et al, 2018). Comorbidity between LD and dyspraxia increases a child's chances of low performance on perceptual motor tasks needed to function normally in daily life. In addition, up to 60% of school time can be dedicated to work on fine motor skills such as handwriting.

Children with learning disabilities and/or attention disorders tend to struggle throughout daily life to execute effective motor planning, or praxis, as deficits in their motor skills are generally present throughout development. However, the root cause of these deficits is still largely unknown (Fidler, Hepburn, Mankin, & Rogers, 2005). When a child possesses both ADHD and LD, their chances of experiencing motor deficits increases. In addition, they are at an increased risk of experiencing various sensory dysfunction that in turn may exacerbate their existing symptoms.

Project Significance

Past studies have explored praxis skills in relation to specific diagnoses such as autism spectrum disorder and Down syndrome, however they omit the integration of sensory processing disorder as a possible factor within analyses. An example of this error can be found in a study conducted by Fidler, Hepburn, Mankin & Rodgers (2005), where young children with Down Syndrome (DS), other developmental disabilities and typically developing children were tested on their praxis abilities. Their findings suggested that young children with DS showed poorer overall motor functioning than the comparison group on all measures, suggesting motor deficits are specific to DS. Other studies tend to focus on behavioral and cognitive functions of certain disorders and their relationship to SPD, but do not explore specific characteristics of the deficits in motor functioning, such as praxis. For example, Shimizu, Bueno & Miranda (2014) studied sensory processing abilities of children with ADHD. Their results indicated that children with ADHD showed significant impairments compared to the control group in sensory processing and modulation and in behavioral and emotional responses. Included in the discussion was the question of to what degree ADHD symptoms described in the DSM-5 are influenced by children seeking sensory stimuli as a behavioral response. As noted in these previous studies, ultimately, the ideas of analyzing deficits in motor functioning and characterizing specific sensory dysfunction in individuals with neurological disorders must be intertwined in future research.

Research to date has failed to identify whether a distinct pattern of sensory processing impairments exists in relation to the core deficits in ADHD. Researchers have posited that "children with SPD display higher levels of inattention, distractibility, over-arousal, and impulsivity than do youth with normal sensory processing" (Dunn, 1997). The theoretical overlap between these behavioral characteristics and the primary symptoms of ADHD (inattention and hyperactivity/impulsivity) make it difficult to distinguish between the two.

Sensory processing disorder is a concept that is generally accepted within the occupational therapy community and other therapy disciplines, however, it is yet to gain full acceptance into the health professional world. By conducting more sensory-based research such as in this study, the credibility of this term will continue to grow. Inconsistent terminology used by therapists, doctors, parents, and insurance companies is inefficient for the child who is suffering from SPD (Kranowitz, 2005). Studies that explore the effects of SPD in relation to aspects of a disorder can allow for the development of sensory profiles that are tailored to specific disorders such as Down syndrome and autism spectrum disorder. Sensory profiles can assist therapists in recognizing

SPD earlier and applying the most effective forms of sensory integration (SI). Sensory processing in relation to a specific aspect of a disorder's criteria is a relatively new way to assess sensory processing. Very few studies break the information down to such a microscopic level to identify these relationships, speaking to the uniqueness of this study.

Purpose and Hypotheses

The purpose of this study is to explore if young children with learning disabilities and/or attention disorders experience praxis deficits due to sensory processing disorder (SPD). The following hypotheses are proposed for this study:

H_1: children with learning disabilities and/or attention disorders will experience praxis deficits due to sensory processing disorder.

H_2: children with a learning disability and/or attention disorders will score higher on average for gross motor praxis skills versus fine motor praxis skills.

Other specific objectives include gaining a better understanding of how sensory processing itself is related to the development of praxis and applying this understanding to observing and analyzing the relationship of SPD and praxis within populations designated as having learning disorders and/or attention disorders. A long-term goal is to better understand SPD relates to deficits in praxis in individuals with various type of neurological disorder(s).

METHODS

Participants

Participants (n=14) ages 8-12 years old were recruited from Starpoint Laboratory School on the Texas Christian University campus. In order to be enrolled at the Starpoint School, children need a formal diagnosis of either a learning disability, ADHD, or both. Of the children that participated, ten had a comorbid diagnosis of both a learning disability and ADHD, three exclusively had a learning disability, and one exclusively had ADHD. While 15 participants were initially recruited, one was excluded due to an injury. There was no other additional inclusion or exclusion criteria indicated at the time of recruitment. In order to start recruitment, the primary investigator informed parents of the purpose and details of the study, including the time commitment, risks, and benefits, via an information sheet. The study protocol was explained to each participant, and he or she gave verbal assent by expressing a willingness to participate in the study. Each participant's parent or guardian signed a university-approved consent form. It was stressed that participation was completely voluntary and that if the child expressed that they no longer wanted to participate in the study, the researcher would contact the parent to discuss whether to continue. Parents were also instructed to contact the primary investigator if they wished to withdraw their child from the study.

Instruments

Praxis Assessment

The praxis assessment included a variety of tasks that evaluated both gross and fine motor skills. The adapted praxis assessment in this study was a modified version of the Test of Gross Motor Development procedure and measurement scale (Hyokju, Kipling Webster, Pitchford, & Ulrich, 2017). The specific gross motor areas measured were balance, bilateral integration and hand-eye coordination. Balance was assessed by having each participant walk heel to toe along a straight line marked by two cones. Jumping jacks were the assigned task to measure bilateral integration, and hand-eye coordination was assessed by having participants throw a tennis ball and a bean bag at a specified Velcro target. Fine motor skill-based tasks included two pencil tasks, during which the participant was sitting at a desk and was asked to copy down a sentence that was previously written by the primary investigator. One sentence was written on a separate piece of paper that the participant was allowed to have on the desk. The second sentence was written on a white board a distance of ten feet away from the participant's desk. Additionally, participants completed an object manipulation task during which they used tongs to individually pick up ten beads and transfer them from a large container to a smaller container. Then, they were asked to pick five beads out of the ten transferred and sequence them onto a necklace string. The last fine motor-based skill was a self-regulation task where a participant was asked to lace a cardboard figure with a shoelace. The participant was able to choose between several lacing cardboard shapes. Each praxis task was graded on a scale from 0-4, and each number had a specific meaning assigned to it. The praxis assessment scores and meanings can be referenced below in Figure 1.

Figure 1: Praxis assessment scores

Score	Meaning
0	No action at all
1	Some movement unrelated to target movement
2	Some movement related to target movement
3	Uncoordinated movement related to target movement
4	Well-coordinated movement related to target movement

Winnie Dunn Child Sensory Profile 2

The Winne Dunn Child Sensory Profile 2 Questionnaire is a standardized form completed by the child's parent or guardian to assess children's sensory processing patterns (Little, Dean, Tomchek, & Dunn, 2018). The questionnaire is separated into item categories: Auditory Processing, Visual Processing, Touch Processing, Movement Processing, Body Position Processing, Oral Sensory Processing, Conduct Associated with Sensory Processing (SP), Social Emotional Responses Associated to SP, and Attentional Responses associated with SP. Items under each category contain statements that describe how a child might act. An example of an item under Auditory Processing is, “My child only pays attention if I speak loudly.” (Appendix A). The options for scoring each item are: almost always (90% or more of the time), frequently (75% of the time), half of the time (50% of the time), occasionally (25% of the time), and almost never (10% or less of the time). If the parent or guardian has not observed the behavior or believes it does not apply, they may check “Does Not Apply.” Each item is associated with a specific quadrant icon. Quadrants are: Seeking, Avoiding, Sensitivity, and Registration. Each quadrant pertains to the degree to which the child either obtains, is bothered by, detects, or misses sensory input. Quadrant and sensory classification information was used by the administrator (primary investigator) of the survey after the items had been scored by the parent or guardian for further interpretation.

Procedure

The praxis assessment was performed at the beginning of the study. This test occurred on-site at the Starpoint School and each test took approximately 15 minutes per participant to complete. The participants were not given specific information on what investigators were examining or looking for but told to complete each task twice. For clarity, tasks could be directed using verbal cues if necessary (i.e. heel to toe task). For jumping jacks, no detailed instructions were given besides “Can you show me 10 jumping jacks?” The only instructions for the pencil tasks were for the participants to copy the sentences seen in front of them. For the lacing task, no specific instructions were given after the participant chose a lacing board. There were three proctors present at each praxis assessment, including the primary investigator. Each proctor was educated about the specific movements associated with each score on the modified praxis scale. For example, a participant who attempted ten jumping jacks by moving their arms and legs up and down but did so out-of-sync would receive a score of three, as the movements observed were related to the target movement but were uncoordinated. The purpose of having three proctors present was to reduce bias and subjectivity. Furthermore, the Winnie Dunn Child Sensory Profile 2 was sent home with each child after the praxis assessments were complete. A handout with instructions on how to complete the questionnaire appropriately was attached to each packet for parents/guardians to reference. The questionnaire takes approximately 20 minutes to complete and was instructed to be returned in each child's backpack by a specific due date. An overview of this study's time commitment broken down by assessment can be observed in Figure 2.

Figure 2: Breakdown of measures and time commitments

Activity	Duration	Purpose
Praxis Test	15 minutes	Assess gross and fine motor praxis skills
Winnie Dunn Sensory Profile	20 minutes	Assess sensory processing patterns
Total	35 minutes	

Statistical Analysis

To describe participants and analyze the praxis assessment scores, descriptive statistics such as mean, standard deviation, and frequency distributions were used. Praxis assessment scores for each task were first averaged between the individual scores assigned by each of the three proctors. Furthermore, the Winnie Dunn Child Sensory Profile 2 uses a normal curve to statistically analyze and interpret the classification system it has put into place (Dunn, 2014). Each child's raw subscores were added up and distributed on the normal distribution curve then categorized based on standard deviations (SD). Each sensory classification had its own standard deviation score range for categorization. Additionally, each item in a sensory category had its own quadrant classification (i.e. sensory seeker). Therefore, each item score was also translated to the participant's sensory quadrant scores. All scores, sensory classifications and quadrants, were interpreted based on SD ranges over a normal distribution curve in order to quantify a participant's sensory profile of behaviors. Individuals that score in the "Just Like the Majority of Others" are within ± 1 (SD) of the mean which signifies sensory processing patterns of the majority of the normative sample. "More Than Others" includes scores + 1 SD and + 2 SD, which indicates that the individual engages in behaviors more than about 84% of the normative sample. "Much More Than Others" includes scores above +2 SD which means individuals engage in behaviors more than about 98% of the normative samples. "Less Than Others" and "Much Less Than Others" scores are reflective of these percentiles except they represent that the individual engages in these behaviors less. Next, Pearson correlations were used to analyze relationships between individual praxis skills and Winnie Dunn sensory categories and quadrants at both the 0.05 and 0.01 significance levels. Frequency distributions were used to compare Winnie Dunn results against each diagnosis (Both LD & ADHD, LD, and ADHD) and the specified sensory category, for example the "visual classification" (Appendix B). Sex differences were not found to be significant based on an independent t-test, therefore both sexes were included in each group. An overview of research goals and statistical tests used to achieve these goals can be observed in the Figure 3 below.

Figure 3: Data Analysis Overview

Research Goal	Data Analysis
Description of participants & praxis assessment scores	Descriptive statistics (mean, SD, frequency distributions)
Interpret Winnie Dunn Questionnaire results	Standard Deviations
Analyze relationships between groups	Pearson correlations
Analyze and compare Winnie Dunn scores within each diagnosis, sensory classification, and the total sample	Frequency distribution
Sex differences	Independent t-test

RESULTS

The descriptive statistics used to quantify the participants' demographic information (diagnosis, gender ratio, and age) can be found below in Figure 4.

Figure 4: Participant demographics

Diagnosis	M:F	Age (years)
Both (LD & ADHD)	7:3	9.90 ± 1.70
LD	2:1	10.67 ± 1.15
ADHD	1:0	12.00 ± 0.00

Praxis Assessment

Participants scored higher on overall average gross motor praxis tasks compared to fine motor tasks. Looking at gross motor skills, participants on average performed the best on the balance skill (heel to toe task) as indicated by a high mean score and low standard deviation. The participants on average scored the lowest on hand-eye coordination, specifically throwing the bean bag for gross motor skills. In regards to fine motor skills, participants on average scored highest on the object manipulation task, using the tongs. The lowest average fine motor score was the self-regulation task, which was lacing a cardboard figure with a shoelace. All praxis averages and standard deviations can be observed in Figure 5 below.

Figure 5: Praxis assessment results

Gross Motor Praxis		Fine Motor Praxis	
Overall Average	3.62	Overall Average	3.54
Overall SD	0.27	Overall SD	0.07
Range	3.35 - 3.89	Range	3.47 - 3.61
Heel to Toe	3.80 ± .19	Far Copying/Chunking	3.55 ± .32
Jumping Jacks	3.79 ± .49	Near Copying/Chunking	3.54 ± .29
Throwing - Ball	3.40 ± .51	Tongs	3.62 ± .28
Throwing - Bean Bag	3.29 ± .52	Lacing	3.44 ± .36

Winnie Dunn Child Sensory Profile 2

Winnie Dunn Child Sensory Profile 2 results indicated that participants with both a learning disability and ADHD most commonly scored “More Than Others”, between one or two standard deviations above the mean, or “Much More Than Others”, above two standard deviations above the mean, in the Visual, Movement, Oral, Conduct, Social-Emotional and Attentional classifications. Their scores also frequently reflected the sensory “Seekers” or sensory “Sensors” quadrants. All participants’ standard deviation categorizations for each sensory classification and quadrant can be observed below in Figure 6 and in Appendix C.

Figure 6: Winnie Dunn SD category frequencies

	Much Less Than Others	**Less Than Others**	**Just Like the Majority of Others**	**More Than Others**	**Much More Than Others**
Seeker		1**	1*** 2** 6*	4*	
Avoider		1**	1*** 2** 8*	1*	1*
Sensor			1*** 3** 6*	2*	2*
Bystander			1*** 3** 9*		1*
Auditory			1*** 3** 8*	2*	
Visual	1*	1**	1*** 2** 5*	5*	
Touch		1** 1*	1*** 2** 6*	3*	
Movement		1**	1*** 2** 6*	4*	
Body Position		1*	1*** 2** 8*	1**	1*
Oral		2*	1*** 3**	1*	3*

			4*		
Conduct		1**	1*** 2** 7*	3*	
Social Emotional		1**	1** 8*	1*** 1** 2*	
Attentional		1**	1*** 2** 7*	3*	

*Both LD & ADHD participants
**LD participants
***ADHD participant

Summary

Overall, relationships between sensory processing and praxis were highly variable making it difficult to establish a relationship. However, using a significance level of 0.01, the self-regulation task (lacing a cardboard figure with a shoelace) was found to have a statistically significant correlation (r) of .689 when compared to the sensitivity quadrant of the Winnie Dunn Questionnaire. The lacing task also achieved statistical significance when correlated to the seeking quadrant (r=.673) and to the oral sensitivity classification (r=.675). Using a significance level of 0.05, the self-regulation task achieved a statistical significance when correlated to the conduct classification (r=.552) and to the movement classification (r=.645). Lastly, the second hand-eye coordination task (throwing a bean bag at a specified target) achieved statistical significance when correlated to the conduct classification (r=.584) (Appendix D).

DISCUSSION

The purpose of this study was to explore if young children with learning disabilities and/or attention disorders experience praxis deficits due to sensory processing disorder (SPD). In order to investigate this topic, two hypotheses were developed.

Hypothesis 1

Hypothesis 1 states that children with learning disabilities and/or attention disorders will experience praxis deficits due to sensory processing disorder. This hypothesis was accepted based on the fact that multiple statistically significant correlations were found using both an alpha of 0.05 and 0.01. Five out of the six significant correlations were based on the self-regulation task, lacing cardboard figure with a shoelace. It was linked to the sensory quadrants of "seeking" and "sensor" and the sensory/behavioral classifications of "oral sensitivity", "movement", and "conduct". These results suggest that individuals with either a learning disability, ADHD, or both tend to experience sensory processing difficulties in the areas of oral sensitivity, movement, and conduct which in turn causes them to have a decreased ability to successfully perform self-regulation tasks. It may also be inferred that children who score in the sensory "seeker" or "sensor" quadrants exhibit behavior that leads to decreased levels of normal functionality in sensory classifications (i.e. oral sensitivity, movement, conduct). This may decrease their ability to perform self-regulation tasks that fall under the fine motor praxis skills category. When examining the relationship between increased conduct, movement, and oral sensitivity dysfunction, low performance scores in the self-regulation category is not surprising. These results coincide with symptoms of ADHD and LD such as loss of planning, low tolerance for waiting, high need for immediate reward, and deficits in self-regulation itself. Therefore, participants most likely had impaired planning when beginning to lace the object and their low tolerance for waiting led to fast performance with many inaccuracies.

Furthermore, the results from the Winnie Dunn Child Sensory Profile 2 yielded results that confirm prior inferences regarding this population's sensory preferences. As listed in the results, many participants scored "More Than Others" or "Much More Than Others" in the sensory "seeking" and "sensitivity" quadrants. Seekers are generalized as having a high threshold for sensory stimuli, meaning sensory experiences are viewed as pleasurable and are craved (Dunn, 2014). This might be observed in an active child who is engaged but seems to lack a consideration for safety. However, this child becomes easily bored in low-stimulus environments, leading to intolerance and thus dysfunction. The "seeking" items in the questionnaire are written to expose the amount the child adds sensory intensity to life activities.

Children who scored "More Than Others" and "Much More Than Others" in the "Sensitivity" quadrant have a low threshold for sensory stimuli. These children have high levels of environmental awareness and have the ability to attend to details (Dunn, 2014). Sensitive children may become overwhelmed and upset when others interrupt their tasks because they are aware of every stimulus but are unable to habituate these stimuli. Sensitivity items are written to expose the amount that a child reacts to sensory input, therefore children above the normative sample react more quickly and intensely than others.

Hypothesis 2

Hypothesis 2 stated that children with a learning disability and/or attention disorders will on average score higher on the gross motor skills in comparison to fine motor skills. This hypothesis was accepted based on the means and standard deviations of the praxis assessments. The overall average gross motor score was $3.62 \pm .27$, while the average fine motor score was $3.54 \pm .07$. Due to the current knowledge of ADHD and LD symptoms previously stated, (i.e. loss of planning, low tolerance for waiting, high need for immediate reward, and deficits in self-regulation) it can be suggested that the participants' fine motor tasks would be either underdeveloped or compromised as a result of these symptoms being exacerbated by sensory processing dysfunction.

The results of this study demonstrated that a child with both a LD and ADHD typically scored lower on fine motor skills and scored higher in terms of responsiveness in sensory classifications. This combination of items led to their categorization in the “seeking” and “sensitivity” distribution quadrants. From the analysis of these interacting factors, it can be suggested that a child with comorbid LD and ADHD may experience decreased or increased sensitivity thresholds that decrease their ability to execute successful praxis, more specifically self-regulation fine motor tasks. This in turn may exacerbate to their existing symptoms leading to dysfunction at school, home, and in the community. Therefore, there is evidence that LD, ADHD, praxis, and SPD are all interrelated and make various contributions to a child’s dysfunction.

Limitations

Limitations in this study include the small sample size (n=14) and the skewed distribution of participant diagnoses. With 10 out of 14 participants having comorbid disorders, it is difficult to distinguish the underlying causes that are intensified by SPD. Additionally, there was no control group as participants were recruited from Starpoint School on TCU’s campus, where the criteria to be a student includes a formal diagnosis of a LD, ADHD, or both. Lastly, the praxis assessment used in this study was adapted from the Test of Gross Motor Development, therefore the reliability and validity of the exact test used is unavailable. Also, the use of three proctors to conduct the praxis assessment can lead to bias and subjectivity. Another limitation was the lack of timing during the praxis assessment. Two subjects could have completed the same task, but during completely different time spans. A 2005 study by Schoemaker, Ketelaars, Zonneveld, Minderaa, and Mulder demonstrated that in typically developing children, the reduction of movement velocity increased accuracy. However, in children with ADHD, reduced movement velocity decreased accuracy. This demonstrates the difference the in amount of time it takes to complete tasks for this population. Future studies should address these limitations to avoid bias and expand the scope of comparison between groups.

Implications and Future Direction

Results from this study provide insight into a child's specific sensory patterns. Although a child may perform overall like a majority of children their age overall, SPD is related to issues with specific sensory patterns that disrupt a child's ability to function properly at home and school. Identifying relationships or predictors of sensory issues could be of benefit to those working with children with learning disabilities or ADHD. A long-term goal is to better understand how SPD relates to deficits in praxis in individuals with various types of disorders. Further research should examine the connection between learning disabilities and motor skills to provide useful information to the special education and occupational therapy fields. By understanding these relationships, children can have an increased chance of normal functioning across various settings, which is the ultimate goal for sensory integration therapy.

Appendix A

Winnie Dunn Child Sensory Profile 2

Items in the "Auditory Processing" subsection

Almost Always = 90% or more	Frequently = 75%	Half the Time = 50%	Occasionally = 25%	Almost Never = 10% or less

AUDITORY Processing

Quadrant	Item	My child...	Almost Always 5	Frequently 4	Half the Time 3	Occasionally 2	Almost Never 1	Does Not Apply 0
AV	1	reacts strongly to unexpected or loud noises (for example, sirens, dog barking, hair dryer).		✗				
AV	2	holds hands over ears to protect them from sound.		✗				
SN	3	struggles to complete tasks when music or TV is on.		✗				
SN	4	is distracted when there is a lot of noise around.	✗					
AV	5	becomes unproductive with background noise (for example, fan, refrigerator).		✗				
SN	6	tunes me out or seems to ignore me.			✗			
SN	7	seems not to hear when I call his or her name (even though hearing is OK).		✗				
RG	8	enjoys strange noises or makes noise(s) for fun.		✗				
		AUDITORY Raw Score	32					

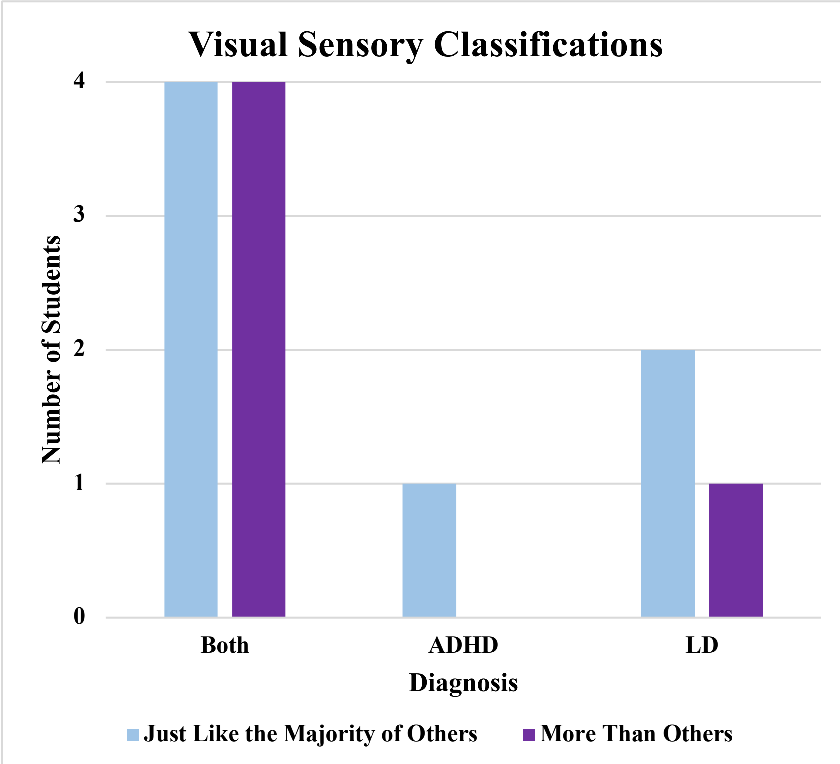
Appendix B

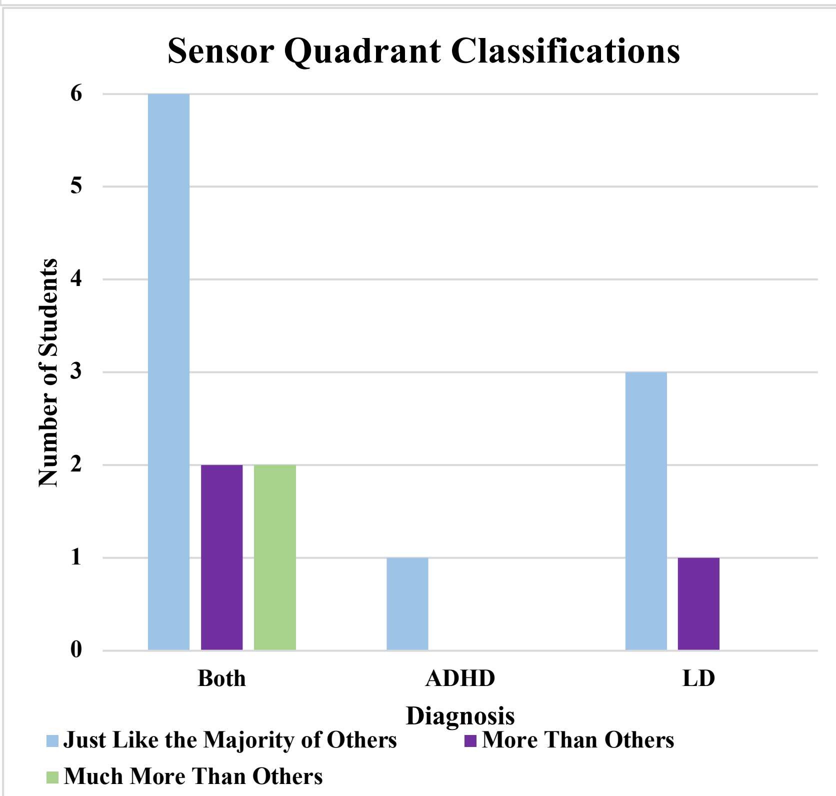
Comparing diagnoses versus sensory classifications (i.e. visual)

			Visual_Classification		Total
			Just like majority	More than others	
Diagnosis	Both (LD & ADHD)	Count	4	5	10
		% within Diagnosis	40.0%	50.0%	100.0%
		% within Visual_Classification	57.1%	100.0%	71.4%
		% of Total	28.6%	35.7%	71.4%
	ADHD	Count	1	0	1
		% within Diagnosis	100.0%	.0%	100.0%
		% within Visual_Classification	14.3%	.0%	7.1%
		% of Total	7.1%	.0%	7.1%
	LD	Count	2	0	3
		% within Diagnosis	66.7%	.0%	100.0%
		% within Visual_Classification	28.6%	.0%	21.4%
		% of Total	14.3%	.0%	21.4%
Total		Count	7	5	14
		% within Diagnosis	50.0%	35.7%	100.0%
		% within Visual_Classification	100.0%	100.0%	100.0%
		% of Total	50.0%	35.7%	100.0%

Appendix C

Frequency distributions of categorizations between diagnoses and sensory classifications





Appendix D

Pearson correlations between praxis skills and sensory classifications/quadrants
**0.05 level and *0.01 level

Correlations

		Seeking_Seeker	Avoiding_Avoider_Raw	Sensitivity_Sensor_Raw
Jumping_Jacks	Pearson Correlation	.012	.188	.235
	Sig. (2-tailed)	.968	.519	.418
	N	14	14	14
Throwing_Ball	Pearson Correlation	.480	-.034	.243
	Sig. (2-tailed)	.082	.908	.403
	N	14	14	14
Throwing_Bean_Bag	Pearson Correlation	-.024	-.097	-.016
	Sig. (2-tailed)	.935	.742	.957
	N	14	14	14
Near_Copying_Chunking	Pearson Correlation	.201	-.124	-.224
	Sig. (2-tailed)	.490	.672	.442
	N	14	14	14
Far_Copying_Chunking	Pearson Correlation	.091	.021	.150
	Sig. (2-tailed)	.757	.944	.608
	N	14	14	14
Tongs_Beads	Pearson Correlation	.081	-.351	-.197
	Sig. (2-tailed)	.783	.219	.500
	N	14	14	14
Lacing	Pearson Correlation	.673**	.153	.689**
	Sig. (2-tailed)	.008	.600	.006
	N	14	14	14
Winnie Dunn	Pearson Correlation	.618*	.681**	.726**
	Sig. (2-tailed)	.019	.007	.003
	N	14	14	14
Visual_Raw	Pearson Correlation	.437	.375	.561*
	Sig. (2-tailed)	.119	.186	.037
	N	14	14	14
Touch_Raw	Pearson Correlation	.658*	.581*	.880**
	Sig. (2-tailed)	.010	.029	.000
	N	14	14	14
Movement_Raw	Pearson Correlation	.819**	.433	.577*
	Sig. (2-tailed)	.000	.122	.031
	N	14	14	14

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