THE INTERACTION OF LANGUAGE, EXECUTIVE FUNCTIONING AND STRUCTURED PHYSICAL ACTIVITY FOR CHILDREN AT RISK FOR SECONDARY COMMUNICATION DISORDERS

by

Jessica Kae Mattingly, M.S., CCC-SLP

Bachelor of Arts in Speech Pathology and Audiology, 2010, Calvin University

Master of Science in Speech Language Pathology, 2012, Vanderbilt University

A Dissertation

Submitted to the Faculty of

Harris College of Nursing and Health Sciences

Texas Christian University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

May

2024

APPROVAL

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Jessica Kae Mattingly, M.S., CCC-SLP

Dissertation approved:

Emily Lund, PhD, CCC-SLP, Major Professor

Daniella Brimo, PhD, CCC-SLP, Committee Member

Robyn Trocchio, PhD, Committee Member

Krystal Werfel, PhD, CCC-SLP, Committee Member

ACKNOWLEDGEMENTS

"I dwell in possibility." As I reflect on these words, written by poet Emily Dickinson, I realize how I have gotten to this very place through the support of people who have allowed me and encouraged me to live that message.

I will eternally be grateful to my mentor, Dr. Emily Lund, for not dismissing my idea to integrate dance into the field of communication sciences and disorders. Sitting in her office that first week of the doctoral program, she challenged me to choose a research interest even if it sounded impossible. Dr. Lund served as the best model of dwelling in possibility during these three years (and I am sure she will continue to as the years pass). I have always known that my getting a PhD would be dependent on finding the right mentor, and I truly believe her expertise and support are what allowed me to accomplish all I have during my time here.

During my time at TCU, I have been surrounded by an excellent faculty that has encouraged my growth and made me truly believe that my ideas were possible. Dr. Baker, thank you for teaching me how to shift paradigms and encouraging me to "wallow" in research possibilities. Dr. Zhang, thank you for going to such great lengths to teach us hard things; there were moments when writing a grant in 6 weeks or designing multilevel models in statistics seemed impossible, but your supreme knowledge and care made those impossible things become possible. Dr. Trocchio, thank you for your expertise in all things motor-based; you have been a great model of interdisciplinary research and mentorship. Dr. Rivera Perez and Dr. Rivera Campos, my teaching mentors, thank you for being the most encouraging and supportive people I have ever known. Even when I had to face some obstacles, you both were nothing but positive and made me feel capable. Not only do you all encourage me to dwell in possibility, but you are excited for what's possible. Your belief in me means so much. Dr. Danielle Brimo, you too have been such a support during my time at TCU. Your transparency during discussions about life after graduate school has truly helped guide me in deciding what I want as my next steps. Mrs. Lynita Yarbrough, thank you for being open to collaboration, spending your valuable time supporting my research. And to all faculty that go unnamed, your support has not gone unnoticed. Every word of encouragement helps me continue this life of possibility.

I cannot speak about my time here in the doctoral program without mentioning my wonderful cohort. Kate, Courtney, and Caleb, thank you for being the people who I can bounce ideas off, share my feelings of imposter syndrome, or just laugh with. From our first semester together, we knew that God, in His perfect timing, brought us together to support each other during this journey. I am so excited to see us all dwell in the possibilities of our futures, and I hope we continue to cross paths.

Thank you to the community partners, participants, and their families I have connected with while pursuing this degree. I have gained so much joy in our interactions. It is an honor to be doing research that will benefit children like you. Thank you for playing such an important role (and for sharing the joy of dance with me!).

Before my time here at TCU, there have been countless people who have encouraged my unconventional pursuit of possibilities. Thank you to Dr. Judith Vander Woude for giving me an opportunity as a college freshman to participate in research. You planted the seed for my interest in a career in research, and you have been a supporter of my journey ever since. To Dr. Peggy Goetz, thank you for entertaining my insistence that I pursue both dance and speech pathology. We never thought that over a decade later I would be researching the integration of the two. Thank you to Ellen Van't Hof who taught me that dance is joy. To Dr. Melanie Schuele, who during my time at Vanderbilt was a model of "dwelling in possibility." Thank you for showing me the humanity in research and intervention and how what we do as researchers truly matters to clinicians and the children we serve. A wealth of gratitude also goes to Dr. Krystal Werfel, who has served as a co-author and mentor during my journey. Thank you for believing in me and my work and showing me all the possibilities that I can dwell in as a scientist. And to the countless children I served as a speech-language pathologist—thank you for letting me in your life, allowing me to help you the best way I knew how. Every single one of you is why I am doing research—to help make communication easier for you.

Outside of my career, there is my family. My mom and dad have always shown me how important education is. My mother sacrificed her own pursuit of possibilities when she dedicated over 20 years to homeschooling my siblings and me. My father worked hard so that homeschooling could be possible but also so that I could pursue dance. With each honor and diploma, my dad has been pushing me to this final degree—well Dad, I did it.

My grandmothers also deserve my gratitude. When I think of strong, faithful women who are guided by love, I think of my grandmothers. They both would laugh if they saw how their lives—my Mamaw serving as a missionary in Brazil and my Grandma working long days on the farm—inspired me to work hard and dwell in possibility.

To my sister Marlena, thank you for being my first competitor, pushing me to meet all the bars you set. When your first and hardest competitor is your sister, it teaches you that there can be love in competition and success can be measured in many ways. To my brother Al, thank you for being an inspiration to start down this path. I knew I loved working with kids by being your big sister, and I knew I wanted to help kids communicate by experiencing your struggles secondhand. To my sister Katrina, thank you for being my person—for keeping me safe as I test the bounds of possibility. I truly know I matter because of you. To my cat Trina, you have been by my side, offering me emotional support, for every single degree, every new job, every cross-country move. Thank you for being my companion as we dwell in possibility.

I have met so many dear people during my "dwelling in possibility," and I am blessed to consider these people friends. Thank you for accepting me and being there, in both laughter and tears. I have no firm definitive place I call "home," yet there are people who are "home" to me. Words simply cannot express the gratitude I feel to these people, for showing me love and support, oftentimes from thousands of miles away.

Finally, I give all glory in this accomplishment and in this lifetime of dwelling in possibility to God. Because of my understanding of His love, I have the heart to show love. "With God all things are possible" (Matthew 19:26).

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ABSTRACT

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Emily Lund, Ph.D., CCC-SLP, Associate Professor

This three-manuscript dissertation evaluates how the domains of language, executive functioning and physical activity interact for children with communication disorders, and how those domains may differentially influence development across different etiologies. The first study explores the relationship between executive functioning and language in children who are deaf and hard of hearing. Parent reports of inattention and hyperactivity are related to child language knowledge and fatigue. The second study evaluates the impact of introducing movement to word learning instruction for children with Down syndrome. More words were learned in the movement condition than in a business-as-usual teaching condition. The third study combines all three domains across etiologies of hearing loss, Down syndrome, and typical development. Results indicate that etiology does impact outcomes in these domains. Executive functioning predicts language outcomes for all children, and etiology impacts this relationship. Further, physical activity interacts with executive functioning skills to strengthen language. The

findings of this dissertation have implications for differentiated language interventions according to disability and incorporation of multiple domains.

CHAPTER I: INTRODUCTION

Background and Significance

One in six children in the United States have one or more developmental disabilities (Cogswell et al., 2022), defined as physical, learning, language, or behavioral impairments that begins during a person's development and lasts into adulthood (Rubin & Crocker, 1989). Out of these 12.5 million children, over 2 million have a diagnosed language disorder (Black et al., 2015). Language disorders can be primary, meaning that it is unattributable to another cause (e.g., Developmental Language Disorder; Bishop et al., 2017); or language disorders can be secondary to another diagnosis, such as Autism Spectrum Disorder, Down syndrome, or hearing loss. In addition to difficulty with spoken language skills (i.e., semantics, syntax, morphology, and pragmatics), children with primary and secondary language disorders often have deficits in literacy (Lund, 2020; Werfel et al., 2015; Snowling et al., 2017) and may or may not have difficulty with cognitive skills, such as executive functioning, including attention and memory (Kronenberger et al., 2020; Sikora et al., 2019; Daunhauer et al., 2017). Given these deficits, children with language disorders are at a profound disadvantage for both academic and social success (Mann et al., 2017). As children age into adulthood, the effects of these deficits continue, having lasting impact on quality of life (Ching et al., 2021).

Traditionally, professionals in the field of communication disorders describe language disorders primarily in terms of a single domain (language) rather than thinking about multiple domain interactions, such as the interaction of the domains of executive functioning and language (Aram & Nation, 1975; Bloom & Lahey, 1978). Though researchers have suggested connections between the domains of language and literacy (Catts et al., 2002; Nation et al., 2004; NICHD Early Childhood Care Research Network, 2005), intervention only recently has focused on using the correlations between language and literacy to improve both skills (Philips et al., 2021; Snowling & Hulme, 2012). This consideration of the link between two separate yet related domains has been of great benefit to children with language-based disorders (Hessling & Schuele, 2020; Mendehlson et al., 2001; Schuele & Boudreau, 2008).

It is estimated that only 55% of children with communication disorders receive intervention (Black et al., 2015). For the children who are served, traditional interventions focus on specific skills within the linguistic domain, such as vocabulary (Wright et al., 2017), figurative language (Benjamin et al., 2020), and syntax (Smith-Lock et al., 2013). Language intervention can be effective (Nye et al., 1987); however, effectiveness can vary greatly depending on etiology and severity of disorder as well as age and setting. Additionally, domain-specific interventions (i.e., interventions that focus solely on an aspect of language) account for less than 50% of variance in growth for children with disabilities (Yoder & Compton, 2004). Skill-specific interventions have variability in generalization or transfer of the skill, making intervention a resource-intensive process (Dyson et al., 2018; Fey, 1988). Moreover, there is a lack of guidelines for evidence-based intervention for language disorders in the schools—the setting where most children receive their services (Gillam & Gillam, 2006). There is a clear need for more evidence-based intervention research as well as an exploration into non-domain-specific interventions.

Theoretical Foundation

Dynamic systems theories offer a mechanistic explanation for how a child's multiple systems work together in development and provide support for considering multiple, rather than only one, system (Smith & Thelen, 2003). A child develops as a whole; but within this whole system, multiple subsystems exist (e.g., motor, cognitive, language). These subsystems are independent, yet they interact to influence development (van Geert, 2000). These systems develop not through a single, principal plan but through the interrelationships of the subsystems and opportunities of the environment, with the key aspects of dynamic systems theory being that development is complex, nonlinear, self-organized, and emergent (Smith & Thelen, 2003). Constraints placed on the system help shape development, by discouraging or encouraging certain changes (Heywood & Getchell, 2021). In motor theories, Newell's model of constraints (1986) describes the constraints that are placed on dynamic systems: structural (e.g., height, weight) and functional (e.g., attention, motivation) individual constraints, physical (e.g., lighting, auditory feedback, temperature) and sociocultural (e.g., gender norms, cultural norms) environmental constraints, and task constraints (e.g., task complexity, instructions/rules, equipment). For example, the individual constraint of motivation could shape and strengthen language growth because a motivated child would be open to more opportunities where language input and exchange can occur; with more input, more development can occur. Applied to language, this would mean that there is not one singular path towards language development; instead, language development happens dynamically as new connections between domains are created and strengthened internally given external opportunities and challenges in the individual and environment (Smith & Thelen, 2003).

The dynamic systems theory of motor movements argues that environmental constraints, task demands, and individual characteristics including age, language skill, and cognitive level impact movement; therefore, a single motor movement, such as kicking your leg, is not fully explained by a linear view of neuronal firing and muscle contractions alone, but is due to a complex series of coordinated but related actions affected by several additional factors (Thelen, 2005). A similar line of thinking can be used when considering language and executive functioning development. For example, when learning new words in a classroom, there may be the environmental challenge of extra noise from the classroom next door. The child could use their attention skills (an individual constraint from the executive functioning domain) to help focus on the task of language learning; hence, a more developed cognitive domain would connect with the language domain and bolster growth in that area.

Further, dynamic systems theory can be directly applied to the link between participation in motor activity, cognition, and language. Opportunities for motor movement provide external opportunities that directly and indirectly develop language and cognition (Iverson, 2010). Early motor advances can have cascading effects on other domains including language (Iverson, 2023). As children develop motor skills, such as sitting and walking, they have access to new opportunities for learning across domains. With this development, opportunities for novel and enriched interactions with both objects and people occur, further supporting language development. Recent research in this area has supported the cascading effects of early motor development into early language development (Iverson, 2021; Schneider & Iverson, 2022; Schneider et al., 2023). In typical development, infants can sit unassisted around 9 months of age (Centers for Disease Control, 2021). By achieving this stage in gross motor development, infants now gain additional information about their physical and social surroundings through vision and fine motor skills like holding, touching, and mouthing. Not only does this exploration allow language learning to occur through the development of categories and descriptors, but it also elicits adult language input. If an infant picks up or mouths a toy, the adult will most likely provide expressive language information, such as labeling (West & Iverson, 2017). Similar cascading effects have been found in infants for other motor development skills. For example, with the onset of walking, children see a rise in initiation of and time in social interactions, including more moving bids (showing items to a communication partner while moving; thus combining domains) and more adult-directed vocalizations and gestures (Clearfield et al., 2008; Clearfield, 2011; Karasik et al., 2011; Walle & Campos, 2014).

Similarly, individual constraints such as cognitive differences shape a child's language and motor development (Thelen, 2005). The dynamic systems model would predict that for children with disabilities, gaps in development of one subsystem would affect the development of another, meaning both language and motor domains could be co-affected systems depending on the type and severity of the disability. Current research supports this suggestion (Iverson, 2021; Mlincek et al., 2022). For infants that are delayed in unassisted sitting, they spend less time in this posture, meaning they experience fewer opportunities for language learning (Leezenbaum & Iverson, 2019). Children who are delayed often spend their motor and attentional resources on the task itself—in this case, sitting—and do not have many available resources left to explore their environment (Mlincek et al., 2022; Woods & Wilcox, 2013). Additionally delays in motor skills, which are typical for children with disabilities, impact the number of social interactions with caregivers which in turn means fewer opportunities for rich, responsive input from the adult (Calabretta et al., 2022). Children's language development is clearly impacted by motor development both directly through the interaction via dynamic systems theory and indirectly via cascading effects.

Overview of Important Literature

Language and Cognition

One domain that has been linked to language for children with secondary language disorders is cognition, specifically executive functioning (Kaczmarek et al., 2018; Sikora et al., 2019). Executive functioning is defined as "a set of active, effortful cognitive control and supervisory oversight processes needed to engage in planned, purposeful, goal-directed behavior" (Kronenberger et al., 2020, p.1129), and it includes inhibition, working memory, mental flexibility, controlled attention, self-monitoring, organization, and goal direction. Both language skills and executive functioning predict academic and social success, impacting a child's overall quality of life (Blair & Raver 2015; Clark et al., 2013). Executive functioning begins to develop at birth and starts to dramatically develop at three years of age, increasing its influence as a child ages and becoming a main predictor of academic achievement during and post middle school (Center on the Developing Child, 2012; Samuels et al., 2016). For children with language disorders, executive functioning plays a major role in both the learning of language and academic success.

The relationship between executive functioning and language has been studied in children who are typically developing and children with language disorders. The neurocognitive domain of executive functioning is believed to have a dynamic relationship with linguistic and auditory domains, effecting and being influenced by early auditory and linguistic experience and activity (Conway & Pisoni, 2008; Conway et al., 2009). Auditory and linguistic stimulation helps the brain develop the following executive functioning skills: sequential processing, pattern detection, serial memory, sustained attention, selective attention, resistance to distraction, and working memory (Conway et al., 2009; Kronenberger & Pisoni, 2018). Spoken language processing has been tied to inhibition, working memory, and cognitive flexibility in typical learners (Khanna et al., 2010; Roberts et al., 2007; Woodard et al., 2016).

For children with degraded auditory input (i.e., children who are deaf and hard of hearing), language skills and executive functioning are both weakened (Nittrouer & Lowenstein, 2022). Because the development of executive functioning is believed to be influenced by early auditory pathway experience and activity, difficulties with executive functioning, including verbal working memory, fluency-speed and inhibition-concentration have been identified in this population even in children who have language development that falls "in the range of normal" on standardized measures (Kronenberger et al., 2020; Kronenberger et al., 2018; Kronenberger et al., 2013). On parent-report measures of executive functioning, children who are deaf and hard of hearing score more poorly than their typically hearing peers on measures of inhibition and working memory (Kronenberger et al., 2020).

For children with more global delays that result in secondary language disorders, the relationship between executive functioning and language is also observed. Children with intellectual disability have executive functioning deficits (i.e., poor inhibition, task initiation, working memory, task monitoring, planning, organization, and attentional shift) as well as language deficits which grow with age (Abbeduto et al., 2007; Loveall et al., 2017; Martin et al., 2009; Tungate & Conners, 2021). In recent research, correlations between receptive and expressive language and the executive functioning skills of inhibition, attention, and working memory were found for young adults with Down syndrome (Kristensen, 2022; Soltani et al., 2022). Expressive language skills are correlated with executive functioning abilities and IQ scores in children with intellectual disabilities; it is believed that having a certain level of language skill is required in order to be able to perform certain executive functioning tasks (Liogier d'Ardhuy et al., 2015).

Executive functioning and language develop concurrently; however, executive functioning abilities have been found to aid language development (Weiland et al, 2014). The relationship may be bi-directional, as language also opens the door to more complex executive functioning skills. This relationship reflects executive functioning's role with learning: executive functioning skills control both actions and thoughts, which are required for learning to occur

(Diamond, 2013). Because overall learning is strongly impacted by executive functioning, language learning is also impacted by executive functioning skills. Improving executive functioning skills can lead to increasing language skills for children with Down Syndrome (Kristensen et al, 2022) as well as varying language disorder etiologies.

Following theories of dynamic systems, advances in executive functioning could lead to development in language. For example, improvements in sustained attention can make word learning easier for children. Word-learning skills then would lead to a more developed vocabulary that could then in turn support executive functioning development by providing more challenging opportunities for sustained attention and working memory to be practiced. A thorough understanding of the relationship between language and executive functioning is a critical step to potentially improving language through executive functioning.

Physical Activity and Language

A second domain that may be impactful for language development in children at risk for secondary language disorders is the motor domain. Physical activity is defined as “any bodily movement produced by skeletal muscles that result in energy expenditure” (Casperson et al., 1985, p.126). Leisure based physical activity includes sports, exercise, and household activities and vary in energy expenditure (Casperson et al., 1985). Leisure-based physical activity can be divided into two categories: structured physical activity and unstructured physical activity. Structured physical activity traditionally has planned objectives with guidance from an instructor; whereas, unstructured physical activity is regarded as free-time or play (Kinder et al., 2020). Although both types of physical activity are important, it is suggested that structured physical activity may offer more benefit to executive functioning development due to higher cognitive load (Diamond, 2014; Subramanian et al., 2015).

The U.S. Department of Health and Human Services have released evidence-based physical activity guidelines for children, recommending that preschool children should be physically active throughout the day (targeting 3 hours daily) and children between the ages of 6 and 17 years should participate in 60 minutes of aerobic physical activity daily (US Department of Health and Human Services, 2018). Recent studies show that most children do not meet this guideline (Michael et al., 2023; Pate et al., 2015). Children with disabilities are often significantly less active than their peers, participating in physical activities at even lower levels (Rimmer & Rowland, 2008; Sit et al., 2007).

Meeting these physical activity guidelines is even more important when you consider the effects on executive functioning. Studies suggest a link between physical activity and executive functioninf, especially if the activity is aerobic in nature (Best, 2010; Chaddock et al., 2011; Fedewa & Ahn, 2011). For example, Luo and colleagues (2023), in a study of 127 typically developing preschoolers, found that those children with high cardiorespiratory fitness also had greater inhibition and working memory. In a review of existing studies, Best (2010) found that chronic and acute forms of physical activity positively impact executive functioning skills, especially if that movement is cognitively engaging. Further, physical fitness levels predict executive functioning outcomes (Chaddock et al., 2011). This may be because executive functioning and proprioceptive performance (i.e., awareness of where one's body is in space) are strongly related in childhood (Gordon-Murer et al., 2021). Good proprioception results in better balance and motor control and requires fewer attentional resources (Česnaitienė et al., 2022). These effects seem to hold true also for children with disabilities (Begel et al., 2022; Cherriere et al., 2020; Lakes et al., 2019). One study utilized a 6-week ballet intervention for children with cerebral palsy and measured its effect on multiple domains; inhibitory control was improved through the intervention (Lakes et al., 2019).

Language scientists have been exploring the connection between physical activity and word learning, a verbal behavior that involves non-verbal cognition (Mellor & Morini, 2023; Pruitt & Morini, 2021; Toumpaniari et al., 2015). For children who are typically developing, aerobic activity aids word learning (Mellor & Morini, 2023; Pruitt & Morini, 2021). Additionally, non-aerobic yet iconic gross-motor movement can help children learn novel words (Toumpaniari et al., 2015). Although there seems to be a relationship between physical activity, cognition, and language that could enhance intervention methods, it has not been explored in children at risk for secondary language disorders.

Relationships Between Manuscripts

Using a dynamic systems theory of development, the three manuscripts of this dissertation seek to evaluate the interrelationships between multiple domains (i.e., executive functioning , language, and motor) for the purpose of understanding how these domains interact dynamically in children at risk for secondary language impairments. The long-term goal of this research is to enhance intervention for children with secondary language disorders by embracing multi-domain approaches.

Manuscript #1, titled *Parent reported ADHD-linked behaviors, fatigue, and language in children who are deaf and hard of hearing,* was authored by Jessica Mattingly, Krystal Werfel, and Emily Lund, and was published in *Perspectives of the ASHA Special Interest Groups* in 2023. This article served as my first exploration of the idea that the domains of cognition and language are correlated in children at risk for secondary language disorders. This first study investigated the executive functioning skill of attention in a population at risk for language disorder secondary to hearing loss. We hypothesized that children who are deaf and hard of hearing would have more reported ADHD-behaviors than children who are typically developing, and that the number of attention-deficit behaviors would be correlated to their language abilities. This article answers questions regarding the correlation between reported attention-deficit behaviors, hearing loss amplification type (i.e., hearing aid vs. cochlear implants), language skills, and cognitive fatigue. It utilizes methods similar to those previously used to evaluate the attention-deficit behaviors of children with primary language disorder (Redmond, 2002). Thus, this study could highlight differences between children with primary and secondary language disorders in terms of the relation between language skills and attention. A future direction of this manuscript was to evaluate the role of executive functioning in the language outcomes of children who are deaf and hard of hearing.

Following the inquiry into the relationship between language and executive functioning domains, a second study asked if a gross motor-based intervention could be useful in treating language, establishing a dynamic relationship between motor movement and language. Manuscript #2, titled *Effects of Dance on Word Learning in Preschool Children with Down Syndrome,* was authored by Jessica Mattingly, R. Lynita Yarbrough, and Emily Lund, and has been submitted for publication. This manuscript introduces the integration of the motor domain via dance in vocabulary intervention to improve outcomes for children with language disorders secondary to Down syndrome. This study evaluates the use of dynamic systems theory-based intervention, and it also evaluates the impact of gross motor movement in providing saliency for learning vocabulary. We hypothesized that intervention that included dance (i.e., gross motor movement) would be more successful than traditional speech-language intervention in teaching new words. A future direction of this research is to further understand the growth of executive functioning skills in children with Down syndrome and how a dynamic systems-based approach could meet this need.

Both manuscripts #1 and #2 highlight the need for a more thorough understanding of the relationships between language, executive functioning, and motor domains. Seeing that children at risk for secondary language disorders differ greatly in their language, executive functioning, and motor abilities according to etiology, it is logical to evaluate the relationship between domains for varying etiologies of language disorder. Manuscript #3, titled *Etiology Differences and the Effects of Physical Activity and Executive Functioning on Language Development,* is being prepared for publication. This third manuscript seeks to provide a more thorough understanding of the relationship between domains for children with secondary language disorders to better inform future interventions that can be more effective in the development of the child as a whole.

Dissertation Purpose

Before investing the time and resources into the development of speech-language interventions which integrate the dynamic systems theory, there is a need to examine how related systems interact to produce outcomes. Additionally, to develop testable hypotheses about how the dynamic systems theory should be incorporated into intervention, it is important to establish how these domains correlate with outcomes for children with secondary language disorders.

The objective of the following three-manuscript dissertation is to evaluate the relationship of multiple domains (i.e., language, executive functioning, and motor) in children at risk for secondary language disorders and examine how it compares among varying etiologies. The long-term goal of this line of research is to explore the relation between multiple domains in children with language disorders to understand how the dynamic systems theory can be used to support better language outcomes.

Together, these three manuscripts further our understanding of the relationship between multiple domains in children with secondary language disorders. The first manuscript informs of the connections between attention and language in children with language disorders secondary to hearing loss. The second manuscript evaluates the integration of the motor and executive functioning domains into language intervention for children with language disorders secondary to Down syndrome. The third manuscript identifies relationships between each, comparing how these relationships differ based on etiology of language disorder. Combined, the manuscripts encourage a paradigm shift, focusing on interactions between domains rather than on domains treated as distinctly developing entities. This work makes translatable contributions to the fields of speech-language pathology, education, and movement therapies by disseminating knowledge on child development. In addition, it identifies ideas for future research that will develop interventions that improve upon traditional therapy practices and result in better quality of life for children at risk for secondary language disorders.

CHAPTER II: PARENT REPORTED ADHD-LINKED BEHAVIORS, FATIGUE, AND LANGUAGE IN CHILDREN WHO ARE DEAF AND HARD OF HEARING

Authors: Jessica Mattingly, Krystal L. Werfel, & Emily Lund

This is the peer reviewed, accepted version of the following article: Mattingly, J., Werfel, K. L., & Lund, E. (2023). Parent-Reported Attention-Deficit/Hyperactivity Disorder–Linked Behaviors, Fatigue, and Language in Children Who Are Deaf and Hard of Hearing. *Perspectives of the ASHA Special Interest Groups*, *8*(6), 1409-1421., which has been published in final form https://doi.org/10.1044/2023_PERSP-23-00086.

Abstract

Purpose: The purpose of this study was to find out if children who are deaf and hard of hearing (DHH), particularly those without substantially delayed language, appear to be at-risk for over-reporting of inattentive and hyperactive behaviors and if ADHD measures are influenced by the presence of language-based items, by child language skills and by child and parent report of fatigue.

Method: This study included 24 children with typical hearing (TH), 13 children with hearing aids (HA), and 16 children with cochlear implants (CI) in second through sixth grade. Parents of children in each group completed a measure reporting on inattentive and hyperactive behaviors, social and academic outcomes, and general fatigue for their child. Children participated in a norm-referenced language assessment and completed a self-report of fatigue.

Results: Analyses revealed an effect of hearing status on overall inattention ratings and social/academic performance: children with CI had significantly lower ratings of inattention and children with HA had more social/academic performance deficits. Differences in inattention scores for children with CI remained even when items biased towards language skills were removed from the measure, but differences in performance for children with HA disappeared. Omnibus language scores significantly correlated with academic and social outcomes, whereas parent report of fatigue significantly correlated with inattention and hyperactivity.

Conclusion: Parent report of behaviors linked with ADHD, including inattention and hyperactivity, is likely influenced by child language knowledge and overall fatigue. Co-morbid diagnosis of ADHD in children who are DHH must consider these factors.

Introduction

Children who are Deaf or hard of hearing (DHH) and use spoken language often struggle with language and literacy in comparison to their typical-hearing peers (Werfel et. al., 2021; Lund, 2016). These language deficits are often linked to overall academic achievement, especially for children with more severe degrees of hearing loss (Tomblin et al., 2020; Sarant et al., 2015). However, given the improvements in hearing technology over previous decades, children who use hearing aids and cochlear implants are also frequently able to attain spoken language scores in the range-of-normal on norm-referenced measures (e.g., Lund et al., 2022; Tomblin et al., 2020). Omnibus norm-referenced assessments may not capture nuanced linguistic difficulties experienced by children who are DHH (Lund, 2020; Breland et al., 2022). Subtle difficulties with language may manifest behaviorally and be interpreted by professionals as co-morbid disorders like Attention Deficit Hyperactivity Disorder (ADHD), particularly if a child does not appear to be struggling substantially with listening (Stevenson et al., 2010). Other populations that struggle with language, like children with specific language impairment, appear at risk for over-diagnosis of ADHD based on test-item construction on across common measures (Redmond et al., 2019; Redmond, 2002). The purpose of this study is to examine parent report of ADHD-behaviors in children who are DHH and use spoken language and to evaluate if language-biases are likely to play a role in suspicion of ADHD.

ADHD and co-occurrence with language disorder

ADHD is one of the most common neurodevelopmental diagnoses in childhood. Hallmark symptoms of ADHD include elevated inattention, hyperactivity, and impulsivity (Barkley, 2006). In 2016, the Center for Disease Control (CDC) reported that 6.1 million children have been diagnosed with ADHD (9.8% prevalence rate) at some point in their childhood; of those children, 6 in 10 had co-occurrence of another mental, emotional, or behavioral disorder (Bitsko et al., 2022). ADHD is most commonly measured in terms of behaviors, such as being off-task, being impulsive, and not following directions (American Psychiatric Association, 2013). However, ADHD is not the only underlying condition that could result in these surface-level behaviors.

Children with language disorders often also demonstrate ADHD-like behaviors, which then could lead to misidentification of ADHD. Children with language disorders are twice as likely to develop and demonstrate behavioral difficulties, including behaviors linked to attention deficit (Yew & O'Kearney, 2013; Chow & Wehby, 2018). These higher levels of problem behaviors could be attributed to avoidance strategies by children with a language disorder. These children may use ADHD-like problem behaviors to avoid academic interactions; when they successfully avoid the academic demand, the problem behavior is reinforced (Kevan, 2003; Sutherland & Morgan, 2003). Similarly, language skills have been found to play a role in self-regulation and active participation during academic activities; children with language disorders may be less engaged during academic instruction which may be perceived as inattention (Chow & Wehby, 2019).

To understand true co-occurrence rates for language disorders and ADHD, it is important to understand the diagnostic criteria for each disorder individually. "Developmental language disorder" (DLD) describes children who have difficulty producing or understanding language that impacts everyday functioning; the language disorder is not due to unfamiliarity with the local language or an associated biomedical condition (e.g., brain injury, Autism Spectrum Disorder, Down's syndrome, or sensorineural hearing loss) and may co-occur with a low level of nonverbal ability (Bishop et al., 2017). In turn, ADHD refers to difficulty with attention, hyperactivity, and impulsiveness that impacts social, academic, and occupational functioning; these difficulties are not better accounted for by a different psychiatric or behavioral disorder (American Psychiatric Association, 2013). When the DSM-V's behavioral criteria for ADHD are reviewed, many of the examples can also be observed in children with DLD; such as, poor listening skills, difficulty completing schoolwork, problems following directions, and forgetfulness. The most current co-occurrence rate for ADHD and DLD is 22.3% (Redmond, 2020), which is much higher than the 9.8% prevalence rate of ADHD in the U.S. It is possible that children with DLD are much more likely to have ADHD than children without DLD; but it is also possible that DLD makes a diagnosis of ADHD more likely. Current research evaluates the co-occurrence between ADHD and primary language disorder; however, there is a need for similar critical inquiry to evaluate the diagnosis of ADHD alongside secondary language disorders (i.e., language disorders stemming from other diagnoses such as Down syndrome, hearing loss, or Autism Spectrum Disorder).

The research on co-occurrence of ADHD and hearing loss is minimal. Many factors impact language outcomes for children who are deaf and hard of hearing (DHH). Hearing history variables such as early age at and consistent use of amplification, shorter duration of deafness before amplification, greater residual hearing, and use of auditory-oral communication likely contribute to higher spoken language outcomes (Geers & Sedey, 2011).

Children who are DHH demonstrate weaker semantic, lexical, and phonological language skills than those of their peers when matched on age and socioeconomic status (Lund, 2016; Pisoni et. al., 2011), and these deficits persist as a child who is DHH ages (Nittrouer et al., 2018; Tomblin et al., 2015). Language outcomes appear to correlate with academic outcomes for children who are DHH who perform more poorly than their TH peers (Tomblin et al., 2020);

these deficits include phonological awareness and emergent literacy skills. (Lund, 2020). Children who are DHH often attain scores on measures of language that fall within the “range of normal” (e.g., Geers et al., 2016); however, that does not indicate that children who score in the normative range do not struggle with more subtle aspects of language: there may be areas of particular weakness that do not show up on tests measures skills across a broad domain (e.g., Lund, 2020). Language difficulties, even subtle ones, may predispose children who are DHH to an ADHD diagnosis similar to children with DLD.

ADHD and Hearing Loss

In its 2009-2010 national survey, Gallaudet Research Institute found only a 5.4% co-occurrence of hearing loss and ADHD, which was lower than the 8-10% diagnosis rate of ADHD in children with typical hearing (Gallaudet Research Institute, 2013). Although parents of school-aged children who are DHH have been found to report more ADHD symptoms than parents of children with TH (Theunissen et al., 2014a), reports of attention difficulties in children with DHH have been overall inconclusive (Theunissen et al., 2014b). Thus, it is difficult to predict whether children who are DHH are likely to be identified as also having symptoms of ADHD.

The American Academy of Pediatrics (AAP) and DSM-V provide guidelines for evaluation and diagnosis of ADHD. ADHD can be classified into three subtypes--Inattentive, Hyperactive-Impulsive, and Combined. A diagnosis of ADHD is made if symptoms are present in at least two settings (APA, 2013). The AAP practice guideline recommends the use of ADHD questionnaires to get reports from parents, teachers, and other school staff (Wolraich, et al., 2019), often via standardized behavioral scales, such as the NICHQ Vanderbilt Assessment Scales (NICHQ; American Academy of Pediatrics et al., 2002).

There exist two well-documented reasons that parents and professionals might be likely to attribute hearing loss-linked behaviors to a comorbid ADHD diagnosis. First, there is an inherent problem in the use of the scales which identify ADHD, which has the potential to impact the overdiagnosis of ADHD in children with primary or secondary language disorders. Heavily linguistic and academic items are present on the questionnaires themselves, blurring the line between language and attention (Redmond, 2002). Examples of linguistically-based behaviors measured by ADHD checklists include not talking, having speech problems, poor schoolwork, poor spelling, not listening, and difficulty completing work. When removing such items from ADHD questionnaires, there was a positive impact on specificity between DLD and ADHD and very little impact on discrimination between ADHD and children who were typically developing (Redmond & Ash, 2014). By removing language and academic items across different behavioral subscales, the specificity for discriminating cases of ADHD and DLD can be improved (Redmond et al., 2019).

A second reason ADHD symptoms might appear present in children who are DHH, beyond measurement-related issues, is listening fatigue. Behaviors that may manifest as inattention actually could be due to listener fatigue, a phenomenon well documented and identified in children who are DHH. Listening fatigue can be considered a type of cognitive fatigue, which is characterized by difficulties in concentration, increased distractibility, anxiety, inattention, and decreases in mental energy and efficiency (Lieberman, 2007; Boksem & Tops, 2008). Listening effort is considered the use of attention and cognition for auditory tasks, such as detecting, decoding, processing, and responding to speech (Bess & Hornsby, 2014). Understandably, school-aged children who are DHH experience greater listening effort than those with TH (Hicks & Tharpe, 2002). Due to this increased effort, children who are DHH report more fatigue than their normal-hearing peers (Hornsby et al., 2014). Also, higher rates of listener fatigue were found for children who are DHH who had poor reading skills than higher-achieving children who are DHH (Camarata et al., 2018), meaning that listener fatigue has a real impact on academic achievement. Interestingly, parents of CI-users report lower levels of chronic fatigue than do the CI-users themselves (Werfel & Hendricks, 2016). Thus, parents may not be fully aware of the fatigue their children experience, and therefore may attribute inattentive (or even hyperactive) behaviors to a cause outside of hearing loss.

In summary, children who are DHH have two characteristics that may result in behaviors that look like ADHD: a) poorer language outcomes and b) greater listening effort and fatigue. Though these difficulties can manifest in ways that appear to be behaviors associated ADHD, they are often part of the hearing loss--not a separate disorder such as ADHD. The surface manifestation of disorders/disabilities such as hearing loss and ADHD may all appear as the same behaviors, but the root of the issue and the treatment for these behaviors are very different. This fact along with the difficulties in measuring ADHD in language-disordered populations (i.e., the presence of language-based items) suggest a possible risk for overdiagnosis of ADHD in the DHH population.

The primary purpose of this study was to find out if children who are DHH, particularly those without substantially delayed language, appear to be at-risk for overdiagnosis of ADHD and if ADHD measures are influenced by the presence of language-based items. The following research questions were addressed:

1. Do parents completing the NICHQ (a measure assessing ADHD behaviors) identify greater prevalence of ADHD-behaviors in children who are DHH who do not have an official ADHD diagnosis versus children with typical hearing?

2. Do children who are DHH score differently on the NICHQ when language-based items are removed compared to peers with typical hearing?

3. Do measures of fatigue and language correlate with parent reports of ADHD behaviors?

Based on the extant literature, it was hypothesized that parents would report greater ADHD prevalence in children who are DHH, reflecting the possible effects of language-biases in measurement (Redmond et. al., 2019) and listening fatigue (Hicks & Tharpe, 2002). An additional hypothesis was that only children who are DHH would have a different profile of performance when language-based items were removed (Redmond & Ash, 2014). The final hypothesis is that measures of fatigue and language will correlate with parent reports of ADHD behaviors, especially for children who are DHH (Hornsby et al., 2002; Geers & Sedey, 2011).

Method

Participants

All procedures in this study were approved by the University of South Carolina Institutional Review Board (as Institutional Review Board of Record), with Texas Christian University in agreement. Students in this study are participants in a larger longitudinal study investigating language and literacy acquisition in children who are DHH (Emergent Language and Literacy Acquisition in Children with Hearing Loss (ELLA); R01 DC017173 funding from the NIH/NIDCD). Children with typical hearing (TH), children with hearing aids (HA), and children with cochlear implants (CI) are recruited to participate in the ELLA study. To participate in the ELLA study, children who have hearing loss must be developing spoken language as a communication modality; that is, no child can only be using a signed language (e.g., American Sign Language). Additional inclusion criteria require children to not have additional diagnosed disabilities known to affect cognitive and/or language development (e.g., Down syndrome).

Participants in the ELLA study who at the time of testing were enrolled in 2nd through 6th grade in schools across the United States were considered to participate in the present study. As a result, this analysis included the parents of 53 children who met that grade criterion from three groups: 24 children with TH, 13 children with HA, and 16 children with CI. It is important to note that the children in this study did not have a medical diagnosis of ADHD at study entry, as was required to meet eligibility criteria for the ELLA study. The grade range of 2nd-6th was specifically chosen for the present study. Although the median age of diagnosis for ADHD is 6.2 years, diagnosis of mild ADHD is around 7 years of age (Visser, et al., 2014). We expected reported symptoms to be "mild," at most, as none of the participants had an early diagnosis of ADHD. U.S. state policies require that a child need only be 6 years of age by the beginning of first grade (TEC §42.003). By setting an eligibility criteria of 2nd grade, the present study highlighted the participants in the 7-year plus range, where mild but notable ADHD-like behaviors were likely to be reported. Table 1 lists the demographic characteristics of the child participants by hearing status.

Table 1. Participant demographics (means and standard deviations) by group.

Variable	TH	HA	CI
Age	112.71 (12.17) months	114.38 (14.11) months	115.44 (14.78) months
Gender	Male: 9 Female:15	Male: 6 Female: 7	Male: 6 Female:10
Race and ethnicity	White: 22 Asian: 1 Hispanic or Latino/a: 2 Prefer not to respond: 1	White: 11 Black: 2 Hispanic or Latino/a: 3	White: 16 Hispanic or Latino/a: 2
Caregiver education level	17.54 (2.62) years	16.92 (3.57) years	15.75 (1.95) years
Hearing loss severity	N/A	Mild: 1 Mild–moderate: 1 Moderate: 3 Moderately severe: 5 Severe: 2 Not reported: 1	Severe: 1 Severe–profound: 4 Profound: 11
Age at diagnosis	N/A	15.63 (17.78) months	3.42 (6.41) months
Age at amplification	N/A	18.67 (17.22) months	6.82 (8.25) months

Note. TH = children with typical hearing; HA = children with hearing aids; CI = children with cochlear implants; N/A = not applicable.

Procedures

Participants in the ELLA study were assessed one-on-one with an examiner in a quiet space (i.e., university laboratories, conference rooms, local public libraries, schools, or their home). Examiners were ASHA-certified speech-language pathologists with experience in test administration. Participants' listening devices (i.e., hearing aid or cochlear implant) were in working condition at the time of testing. Children were allowed breaks as needed to encourage continued participation. Test administration was video- and audio- recorded to calculate scoring reliability and procedural fidelity. A parent of each participant completed questionnaires, including the NICHQ measure. Study data were managed using REDCAP electronic data capture tools hosted at University of South Carolina and at Boys Town National Research Hospital (Harris et al., 2009). Participants completed a battery of language and literacy testing during testing sessions that lasted approximately 2 hours. Breaks were allowed as needed, and testing could be spread over multiple days.

Measures

Attention Measure. The *National Institutes for Children's Health Quality Vanderbilt Assessment Scales* (NICHQ; American Academy of Pediatrics et al., 2002) parent rating form was given to the parent of each participant. Designed to be used in combination with other measures to diagnose ADHD in children between the ages of 6 and 12, the NICHQ questionnaire is based on daily observations of a child. The NICHQ has a symptom assessment and impairment in performance assessment. The first 9 questions of the NICHQ captures symptoms of *Inattention*, and the second set of 9 questions captures symptoms of *Hyperactivity.* Additionally, the remaining symptom-based items (19-47) capture behaviors associated with Oppositional-

Defiant Disorder, Conduct Disorder, and Anxiety/Depression. The impairment in performance questions (48-55) measure potential impairment caused by the symptoms, including academics and social skills.

On the NICHQ, symptoms (items 1-47) are rated as occurring “never,", "occasionally,” “often,” or “very often” when applied to the child’s behavior; items were scored 0 to 3, with “never” being scored 0 and “very often” being scored “3”. Responses were considered “positive” if they were scored 2 or 3. On the impairment in performance items, parents rate items as “excellent,” “above average,” “average,” “somewhat of a problem,” or “problematic,” scoring 1-5 respectively. Responses were considered “positive” for these items if they had a score of 4 or 5.

For diagnostic purposes, children must meet two criteria. First, they must have 6 out 9 positive responses in the inattention section for an ADHD-Inattentive diagnosis; 6 out 9 positive responses in the hyperactivity section for an ADHD-Hyperactive/Impulsive diagnosis; or 6 out of 18 positive responses for an ADHD Combined diagnosis. Second, they must have a positive response on one of the performance questions. For this study, four scores were collected for each participant from the NICHQ: inattention subtest score (items 1-9), hyperactivity subtest score (items 10-18), total symptom score (TSS; items 1-47), and average performance score (APS; the average score on items 48-55).

Alternative Scoring. Each item on the NICHQ was categorized as language-based vs. non-language-based, following the example provided by Redmond on similar assessment tools (Redmond, 2002; Redmond et al., 2019). In these previous studies, items were removed that were “symptomatic of a primary language impairment or representative of a secondary academic consequence" (Redmond et al., 2019). A list of the items that Redmond removed in his studies was used as a reference tool for three speech-language pathologists to judge whether items on the NICHQ should or should not be removed. Agreement across SLPs was above 80% in point-by-point comparison, and the first author's designations were used for the study. Table 2 shows the items removed from the NICHQ for the alternative scoring. In total, 15 items were removed.

Table 2. Items removed from National Institute for Children's Health Quality Vanderbilt Assessment Scales due to language bias.

Responder	Section	Language items
Parent	Inattention	• Does not pay attention to details or makes careless mistakes with, for example, homework • Has difficulty keeping attention to what needs to be done • Does not seem to listen when spoken to directly • Does not follow through when given directions and fails to finish activities (not due to refusal or failure to understand) • Has difficulty organizing tasks and activities • Avoids, dislikes, or does not want to start tasks that require ongoing mental effort • Is forgetful in daily activities
	Hyperactivity	• Talks too much • Blurts out answers before questions have been completed • Has difficulty waiting his or her turn • Interrupts or intrudes in on others' conversations and/or activities
	Academic performance	• Reading • Writing • Mathematics
	Social performance	• Relationship with peers • Participation in organized activities (e.g., teams)

Language Measure. The *Clinical Evaluation of Language Fundamentals-Fifth Edition* (CELF-5; Wiig, et al., 2013) was used as the omnibus language measure. Subtest scaled scores resulted in the Core Language Score. Standardized administration and scoring procedures were followed, as outlined in the manual.

Fatigue Measure. The *Pediatric Quality of Life Inventory: Multidimensional Fatigue Scale* (PedsQL; Varni, 1998) was used to measure child and parent reported fatigue. The Young Child (5-7) and Child (8-12) self-report forms were used. Each self-report form has 18 statements: 6 regarding general fatigue (e.g., "I feel tired."), 6 regarding sleep and rest fatigue (e.g., "I sleep a lot."), and 6 regarding cognitive fatigue (e.g., "It is hard for me to keep my attention on things."). These statements are rated from "never" or "not at all" to "always" or "a lot" with scores ranging from 0 to 4, respectively. These ratings are then converted to scores, with higher scores indicating lower levels of fatigue. Children under age 8 were asked to respond by pointing to a visual to rate the statement (smiling face for "not at all," straight expression for "sometimes," and frowning face for "a lot." Children over 8 answered verbally. Parent report forms were also used, containing the same 18 statements and ratings (0 "never" to 4 "almost always), and were read and answered by hand.

Results

Means and standard deviations for the NICHQ, CELF-5 core language score, and Peds-QL Overall Fatigue score are all reported by group in Table 3. Upon overall descriptive review of NICHQ results, one child with TH and two children with HA met the diagnostic criteria for ADHD on the NICHQ (which is not an official diagnosis of ADHD and would need to be confirmed; the NICHQ is only a piece of an overall test battery, and additional information such as a teacher report is necessary for a diagnosis of ADHD). All 53 participants had complete NICHQ parent reports, 50 participants had complete CELF-5 assessments (those not completed were eliminated from the testing battery because the participant ran out of time in the battery or became non-compliant after participating in the large test battery), 43 had complete Peds-QL self-reports (again, some were eliminated from the battery because the participant ran out of time), and 48 had complete Peds-QL parent reports (5 parents never turned in the form). Missing reports included the following: 2 TH and 1 CI had a missing CELF-5 core language score; 5 TH, 3 CI, and 2 HA had missing PedsQL child reports; 3 TH and 2 HA had missing PedsQL parent reports.

Table 3. Descriptive information and assessments (means and standard deviations) by group.

Assessment	TH	HA	CI
Inattention (unaltered)	7.67 (6.13)	9.69 (5.71)	4.5 (3.08)
Hyperactivity (unaltered)	6.21 (6.14)	7.31 (6.51)	3.31 (2.33)
Total symptom score (unaltered)	23.13 (19.01)	25.69 (14.11)	12.25 (7.33)
Average performance score (unaltered)	1.88 (0.54)	2.45 (0.66)	1.95 (0.53)
Inattention (language-biased items removed)	1.96 (1.37)	2.54 (1.51)	1.25 (0.77)
Hyperactivity (language-biased items removed)	2.46 (3.23)	4.00 (4.22)	0.88 (0.81)
Total symptom score (language-biased items removed)	13.67 (11.62)	15.15 (8.66)	6.69 (4.48)
Average performance score (language-biased items removed)	1.67 (0.82)	1.81 (0.75)	1.56 (0.68)
CELF-5 Core Language score	114.82 (22.47)	95.38 (13.52)	96.93 (18.87)
PedsQL-MFS overall fatigue score: child self-report	64.83 (13.62)	62.9 (16.16)	59.3 (11.77)
PedsQL-MFS overall fatigue score: parent report	83.60 (15.29)	74.24 (13.01)	85.00 (12.65)

Note. Standard deviations in parentheses. TH = children with typical hearing; HA = children with hearing aids; CI = children with cochlear implants; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition (Wiig et al., 2013); PedsQL-MFS = Pediatric Quality of Life Inventory: Multidimensional Fatigue Scale (Varni, 1998).

The first research question asked if parents identified a greater prevalence of ADHD-behaviors in children who are DHH than in children with TH. Prior to conducting an ANOVA, multiple assumptions were tested and the dependent variables (Inattention subscale, Hyperactivity subscale, TSS subscale, and APS subscale) violated assumptions of normality and homogeneity of variances. To address these violated assumptions, nonparametric testing was conducted.

The Kruskal-Wallis one-way ANOVA was conducted with hearing status group (TH, HA, CI) as the independent variable and inattention, hyperactivity, TSS, and APS subscale scores as dependent variables. There was a main effect of group on Inattention (H (2) = 6.05, p = .048) with a small effect size (η^2=.04), TSS (H(2) = 6.24, p=.044) with a small effect size

(η^2=.05), and APS (H(2) = 8.1, p=.017) with a moderate effect size (η^2=.08). There was not a main effect of group on Hyperactivity, (H(2) = 2.59, p = .274). Pairwise comparisons between hearing status groups with Bonferroni correction found a significant difference between CI and HA for the Inattention subscale (p=.044), and TSS (p=.048). TH and HA were also significantly different for APS (p=.02).

The second research question asked whether children who are DHH score differently than children with TH on the NICHQ measure when language-based items were removed. A Kruskal-Wallis one-way ANOVA was again conducted with hearing status group (TH, HA, CI) as the independent variable and the altered scores for inattention, hyperactivity, TSS, and APS subscales as dependent variables.

There was a main effect of group on Inattention (H (2) = 7.11, p = .029) with a small to moderate effect size (η^2=.06) and TSS (H(2) = 7.01, p=.03) with a small to moderate effect size (η^2=.06). There was not a main effect of group on Hyperactivity, (H(2) = 4.03, p = .133) or APS (H(2) =.97, p=.62). Pairwise comparisons between hearing status groups with Bonferroni correction found a significant difference between CI and HA for Inattention (p=.027) and TSS (p=.0035).

The third research question asked whether there was a significant correlation in performance between the NICHQ subscales and omnibus language testing (CELF-5 core language standard score) or between the NICHQ subscales and fatigue assessments (child and parent report). Prior to conducting a Pearson Correlation analysis, multiple assumptions were tested and the NICHQ scores violated normality assumptions. For this reason, correlation using Kendal's tau was used in analysis.

Language. Core language scores were significantly negatively correlated with unaltered APS scores for all participants (τ_b=-.31, *p*=.002), meaning lower CELF-5 scores correlated with higher reports of impaired academic and social performance. Language scores were not significantly correlated with any other NICHQ measure (both unaltered and altered). See Table 4 for all correlations with language.

Table 4. Correlations between NICHQ and language and fatigue (Kendall's tau and *p* value).

Measure	Inattention (unaltered)	Hyperactivity (unaltered)	TSS (unaltered)	APS (unaltered)	Inattention (altered)	Hyperactivity (altered)	TSS (altered)	APS (altered)
CELF-5 Core Language	−.14 (.173)	−.05 (.595)	−.11 (.268)	−.31** (.002)	−.08 (.458)	−.05 (.654)	−.09 (.378)	−.07 (.509)
PedsQL-MFS child	−.25* (.022)	−.16 (.152)	−.18 (.095)	−.27* (.013)	−.25* (.033)	−.143 (.211)	−.15 (.160)	−.18 (.129)
PedsQL-MFS parent	−.47*** (< .001)	−.40*** (< .001)	−.49*** (< .001)	−.31** (.003)	−.425*** (< .001)	−.327** (.003)	−.48*** (<.001)	−.12 .267

Note. NICHQ = National Institute for Children's Health Quality Vanderbilt Assessment Scales (American Academy of Pediatrics et al., 2002); TSS = total symptom score; APS = average performance score; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition (Wiig et al., 2013); PedsQL-MFS = Pediatric Quality of Life Inventory: Multidimensional Fatigue Scale (Varni, 1998).

*$p < .05$. **$p < .01$. ***$p < .001$.

Fatigue. First, correlations between NICHQ scores and Peds-QL child self-report of overall fatigue were conducted. Self-report of fatigue was significantly negatively correlated with unaltered inattention scores (τ_b=-.334, *p*=.029), unaltered APS scores (τ_b=-.42, *p*=.0005), and altered inattention scores (τ_b=-.367, *p*=.015). See Table 4 for all correlations with self-report of fatigue. A negative correlation indicates that children who reported more fatigue also presented with more behaviors associated with inattention and with impaired academic and social performance.

Next, correlations between NICHQ scores and Peds-QL parent-report of overall fatigue were conducted. Parent report of fatigue was significantly negatively correlated with all NICHQ measures except altered APS score. This negative correlation indicates that parents who reported more symptoms of fatigue in their children also reported more inattention and hyperactivity (even after language-based items were removed). See Table 4 for all correlations with self-report of fatigue.

Discussion

This study compared parent reports of ADHD-associated behaviors of children with hearing aids, children with cochlear implants, and children with typical hearing to determine if there were differences between groups and if these differences correlated with language skills and/or measures of fatigue. There was a significant effect of hearing status on the overall inattention ratings, total symptoms score, and average performance score of the NICHQ. Analyses showed that children with CI had significantly lower ratings of inattention and overall symptoms than children with HA. Additionally, children with HA had higher APS performance scores (i.e., greater levels of impaired academic/ social performance) than children with TH, whereas children with CI did not. Thus, it appears that children with CI show fewer symptoms of inattention than children with HA. Although the overall group means (Table 2) indicates that children with TH had inattention scores falling between the hearing loss groups, their scores were numerically more closely aligned with children with HA than children with CI. However, children with HA in this sample had more difficulty with academic and social performance than children with TH, and in this case, children with CI and children with TH had average performances and standard deviations that were more closely aligned. In other words, it appears children with CI had the fewest symptoms of inattention, and children with HA had the most difficult with academic and social performance.

To address the role of language in perceived differences in inattention, hyperactivity, and performance, we (a) removed language-based items for the NICHQ to evaluate differences in performance and (b) considered how omnibus language scores correlated with NICHQ results. When language-biased items were removed from the NICHQ, the children with CI continued to have significantly lower inattention and total symptom scores than children with HA. However, average performance scores were no longer significantly different between the TH and HA groups. Standard scores (which are indexed to a child's age) on the CELF-5, an omnibus language measure, correlated with the average performance scores on the unaltered NICHQ, meaning lower language scores were associated with greater levels of impaired academic and social performance. With the removal of language-biased items on the NICHQ, there was no longer a correlation between omnibus language knowledge and score on the NICHQ. Thus, it appears that language items on the NICHQ did not drive the significantly lower performance of children with CI on this subscale. However, differences in language performance did relate to the language and social performance deficits of children with HA.

Fatigue was another hypothesized contributor to symptoms of inattention or hyperactivity that might be observed in children who are DHH. Both child-report and parent-reports of fatigue, via the PedsQL measure, correlated with inattention and average performance scores. That is, when parents or children reported higher levels of child fatigue, those children tended to have higher levels of inattention and impaired social and academic performance. Both parent and child report of fatigue was no longer significantly correlated with social/academic performance once language-based items were removed. Only parent reports of fatigue also correlated with hyperactivity and total symptom scores, even once language-based items were removed from those scales. In other words, there appeared to be a relation between parent reports of fatigue and parent reports of inattention and hyperactivity and a relation between child reports of fatigue and parent reports related to inattention. Any fatigue-correlations related to average performance score appeared to be influenced by language-based items.

There are many possible shared symptoms between ADHD and levels of substantial fatigue, such as inattention, hyperactivity, and depression, and ADHD severity has been found to significantly predict fatigue intensity in both children and adults with chronic fatigue syndrome (Saez-Francas et al., 2012). Children who are DHH already are at an increased risk for difficulties with academics, and the increased levels of listening fatigue puts them at a further disadvantage (Bess et al., 2020; Fitzpatrick et al., 2019). Correlations between fatigue and symptoms of inattention and hyperactivity were significant and highlight a possible area of clinical concern: parents may be inclined to interpret signs of fatigue as symptoms of ADHD. For children at risk for high levels of fatigue (like children who are DHH), this is an important distinction for accurate diagnosis.

The removal of language-biased items on the NICHQ did not support the authors' original hypotheses. Given the findings with children with DLD (Redmond & Ash, 2014), it was expected that for both HA and CI removal of language items would result in fewer reported inattentive and hyperactive behaviors. Instead in our sample, the children with CI scored very low compared to children with HA on the NICHQ measures of inattention, especially after the language-biased items were removed. Also, children with CI had a small range of scores, reflected by a small standard deviation. Language level did not provide an explanation for the performance of children with CI on the inattention subscale.

Additionally, fatigue levels did not provide an explanation for the lower performance of children with CI on the inattention scale (with or without language-based items removed). That is not to say that children with CI did not experience cognitive fatigue; numerically, children with CI had the lowest self-reported average on the Peds-QL (indicating higher levels of fatigue when compared to children with HA and children with TH). Children with CI may experience fatigue differently than children with HA. The effort involved in listening through a CI (i.e., the focused attention expended by children with CI to cope with difficulties listening) may be what drives fatigue, rather than fatigue causing inattention. A final possibility is that another unknown factor beyond fatigue or language level makes it appear that children with CI have few symptoms of inattention.

The NICHQ's correlation with language was only significant for average performance score before language-based items were removed. The average performance score (APS) measures potential impairment caused by ADHD symptoms, including deficits in academics and social skills. Low APS ratings on the NICHQ translate to better academic and social skills. Higher language scores correlated with lower APS ratings on the NICHQ. Language is highly related to academic and social success for all children (Chow & Hollo, 2022; Chow & Wehby, 2018; Kaiser et al., 2022), and is especially true for the DHH (Tomblin et al., 2020; Nittrouer et al., 2018). The correlation of language scores with academic and social performance items on the NICHQ reflects this known relationship between language and academic and social skill. Language scores did not correlate with the other "symptom-based" items on the NICHQ.

On the unaltered NICHQ, children with HA scored significantly higher on reports of impaired social and academic performance than TH peers. Children with HA can have social and academic deficits when compared to their TH peers (Tomblin et al., 2020; Lund et al., 2022). The higher APS scores for children with HA reflect the parent's perception of these difficulties and again, highlight a potential clinical issue. If parents are encouraged to consider an ADHD diagnosis for their child with HA, it is possible that a measure like the NICHQ would incline parents to attribute difficulties with academics and social skills to something other than the hearing loss. Future work may consider how language difficulties and fatigue manifest behaviorally for children with HA.

This study chose to explore the possibility of ADHD-symptom reporting in children who are DHH who use spoken language relatively well: that is, children who did not have other diagnoses likely to limit their language growth and who did not have diagnosed ADHD at study entry (and would likely only have mild ADHD behaviors if any). Average scores of children in the CI and HA groups on the CELF-5 were well within the range of normal but below those of peers with TH, meaning any language struggles of children with CI and HA were often somewhat subtle (e.g., Lund, 2020). It seems likely that subtle difficulties are those most likely to be misinterpreted. These subtle differences may not result in an ADHD referral or diagnosis, but they can cause problematic judgments of child behavior. An adult may confuse fatigue for inattention and the actions taken to correct the inattentive behavior will be ineffective. It is important that adults working with children who are DHH be aware of the relation between behavior, language, and fatigue, and not jump to conclusions about a secondary diagnosis.

Because the inclusionary criteria for this study involved diagnoses at study entry, it is also possible that children in the sample actually did have later-emerging ADHD as a diagnosis co-morbid with hearing loss. In fact, there were two children with HA and 1 child with TH in this sample who met diagnostic criteria for ADHD concern using the unaltered NICHQ score. A closer analysis of the performance of these children may give us insight about the possibility of true co-occurrence with ADHD. The child with TH had high ratings in all areas—inattention, hyperactivity, and average performance score. He also scored high on the questions screening for oppositional defiant disorder. With the removal of language-based items, he still had high scores in all areas which were well above group means. For this child with TH, the findings between altered and unaltered NICHQ were comparable, and diagnostic accuracy is suggested. For one child with HA who met diagnostic criteria for ADHD, reports of inattention and academic and social performance drove the NICHQ elevated scores. On the altered form of the NICHQ (where language-biased items were removed), her inattention score fell within the range of overall group means; however, APS ratings were still high. For this child, NICHQ performance appears to have been heavily linked to language skills and academic performance. We believe this child's profile reflects language difficulty. In this case, an ADHD diagnosis should proceed with caution (and be administered by individuals familiar with hearing loss). For the second child with HA, hyperactivity scores drove the NICHQ results that indicated impairment. Even with removal of language items, this child's hyperactivity scores were still well above the group mean. For this child, it seems there is a possible true co-occurrence of ADHD with hearing loss. Looking at these two children shows that to measure true co-occurrence, language-bias in measurement should at least be considered.

Limitations and Future Directions

This work provides avenues for future study of the link between co-morbid diagnosis of ADHD and hearing loss, and for the link between behavior, language, and fatigue. A limitation of this study is that the average age of participants was 9.5 years. Only 50% of children who will be diagnosed with ADHD are diagnosed by the age of 7 (Kessler et al., 2005). A large number of children demonstrate symptoms of ADHD-like behaviors as academic demands increase. Language difficulties can persist as a child who is DHH ages, impacting academic performance at the higher grades (Nittrouer et al., 2018; Tomblin et al., 2020). As academic and language demands increase, mild ADHD-like behaviors may worsen and could change the findings of the study. Future research might consider a similar study with children from a higher age range, including middle and high school. Additionally, future work might expand the participant population to include children who do have more severe struggles with language and/or signs of ADHD at an early age.

Another limitation of this work is that this study focuses solely on parent report. Teachers are often the first to suggest a diagnosis of ADHD even before parents (Sax & Kautz, 2003). Additionally, teacher reports have been found to be more sensitive to identifying hyperactivity than parent reports (Goodman et al., 2000). Overall, there are low rates of agreement between parent and teacher reports of ADHD (Wolraich et al., 2004). It would be beneficial to compare teacher reports of ADHD-behaviors with parent reports for this population.

In this sample, ADHD-behaviors (inattention and hyperactivity) correlated with reports of fatigue. In future research, exploration of other possible reasons for the ADHD-behavior differences between children who are DHH and children who are TH would be beneficial. A possible explanation of group differences identified in this study relates to how fatigue manifests behaviorally in children with CI versus HA. Another possible explanation for differences in behavior is executive functioning. Attention, which was measured in this study, underlies all executive functioning skills, serving as a gateway to more complex abilities (Garon et al., 2008). By definition, ADHD is an associated disorder of executive functioning (Barkley, 1997a). Additionally, executive functioning is influenced by early auditory and linguistic experience and activity, aiding the brain in development of sequencing, memory, attention, and inhibition (Conway et al., 2009; Kronenberger & Pisoni, 2018). Future research may further explore the executive functioning connection, by using measures such as the Flanker task for inhibitory control and attention or a behavior rating inventory looking at all executive functioning skills to determine how those skills relate to perceived symptoms of ADHD.

Conclusion

Overall, this study provides knowledge that there is a difference in the reporting of ADHD-like behaviors in some children who are DHH versus children with TH. Children who use hearing aids having significantly more academic and social behaviors reported than children who use cochlear implants, and children who use cochlear implants score significantly lower on inattention behaviors. Removal of language-based items only substantially impacted group differences on academic and social behaviors (but not inattention). Omnibus language scores were significantly correlated with academic and social performance ratings and fatigue scores, especially as reported by parents, significantly correlated with inattentive and hyperactive behaviors. It is important that parents and teachers of children who are DHH are mindful of these differences and the unique needs of their children.

Acknowledgements

This work was funded by a grant from NIH/NIDCD (R01DC017173; PIs: Werfel & Lund). The contributions of the ELLA study team are gratefully acknowledged.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

CHAPTER III: THE EFFECTS OF ADDING DANCE MOVEMENTS TO INTERVENTION ON WORD LEARNING IN CHILDREN WITH DOWN SYNDROME

Authors: Jessica Mattingly, Rosalyna Yarbrough, & Emily Lund

Abstract

Purpose: This preliminary study investigated the effect of adding movement through dance to word-learning instruction of preschool children with Down syndrome as compared to the effect of traditional word-learning instruction (i.e., speech-language therapy).

Methods: In a crossover design study, 21 preschool-aged children received 12 sessions of movement-based vocabulary instruction while continuing to receive traditional intervention. Vocabulary probes were administered before intervention and every 3 weeks, and observations in each intervention setting measuring engagement were also made. Additionally, teacher reports of executive functioning skills were collected.

Results: A repeated measures ANOVA revealed that preschool-aged children with and without Down syndrome gained significantly more words taught via movement than traditional intervention. Engagement in sessions did not significantly differ between intervention types. Although there were correlations between words learned in traditional intervention and executive functioning skills, no correlations were found between words learned in the movement intervention and executive functioning skills.

Conclusions: This study supports the use of movement in speech-language therapy to teach vocabulary for preschool-aged children, especially those with Down syndrome.

Introduction

Spoken language delays are among the most common areas of weakness for children born with Down syndrome (DS) and can be more excessive than nonverbal intellectual delays (Abbeduto et al., 2007; Martin et al., 2009). Specifically, vocabulary knowledge is often delayed in children with DS (Caselli et al., 2008; Laws et al., 2015; Warren et al., 2008); yet, relatively little is known about best practices and vocabulary interventions for children with DS (Jordan et al., 2011). Deficits in cognitive skills in children with DS may exacerbate their language learning difficulties. Even young children with DS exhibit issues with working memory, planning, and inhibitory control (Daunhauer, 2014). Recent research has found positive correlations between language skill and motor ability (Mule et al., 2022); however, children with DS experience motor deficits due to lower muscle tone (hypotonia) and weaker core strength (Vandoni et al.; 2023). It is possible, given cognitive and motor delays associated with DS, that children with DS need additional intervention considerations as compared to children with vocabulary delays that do not include cognitive and motor delay. Research suggests that addressing other domains alongside language learning can lead to increasing language/vocabulary skills (Kristensen, 2022). The purpose of this study is to evaluate the effect of adding engaging movement through dance to word-learning instruction of preschool children with Down syndrome as compared to the effect of traditional word-learning instruction.

Vocabulary in Down syndrome

Children with DS experience profound delays in oral vocabulary, often falling short of developmental milestones by 3+ years (Berglund, 2001). In contrast to typically developing children who have around 50 words in their expressive vocabulary and start combining words into phrases by the age of 18 months, children with DS reach these language and vocabulary developmental milestones much later (Naess et al., 2021). Children with DS exhibit specific deficits in semantic knowledge, having particular difficulty with vocabulary knowledge depth (Laws et al., 2015; Michael et al., 2012). For example, children with DS have a better receptive knowledge of nouns than verbs (Loveall et al., 2016), and they use significantly fewer verbs than their typically developing peers (Loveall et al., 2019; Michael et al., 2012). Larger vocabularies during the preschool years correlate with better language, reading, and cognitive outcomes for children (Marchman & Fernald, 2008). These domains are continued areas of concern for children with DS as they age, meaning effective intervention during preschool and early elementary is of high importance to the future functional independence of children with DS.

Effective vocabulary interventions are in high-demand, and research-based interventions with unbiased outcomes are in short supply for this population (Smith et al., 2020). Extant research indicates children with Down syndrome can improve their vocabulary knowledge through responsive interventions which use child communication acts to guide feedback decisions (e.g., Warren et al., 2008; Yoder & Warren, 2004). High-dose frequency treatments (i.e., 5 times per week) in comparison to low-dose frequency treatments (i.e., 1 time per week) lead to better word learning in children with DS (Yoder et al., 2014). Traditional language intervention (i.e., both systematic and naturalistic approaches) has the potential to help children with DS; however, interventions have had minimal transfer effects (both near and far; Smith et al., 2020). This means that when a child learns one item, for example the use of the word “no,” it does not facilitate learning of a second language item, such as the word “not.” Each item must be learned individually, and thus skills do not easily generalize away from the intervention context. Overall, current intervention for children with DS requires a large investment of time and effort, and other means of improving intervention should be explored.

Saliency

The theory of saliency provides another avenue via which researchers and educators can explore improving word-learning intervention. The theory posits that objects have properties that make them stand out, which capture and keep attention during item labeling and can feed into word learning. Saliency is even more important for young learners or delayed learners who have not mastered understanding of semantic and pragmatic cues for learning words (Pruden et al., 2006). Social interaction, specifically joint attention and joint action, enhances the saliency of words and makes them relevant to the learner (Wildt et al., 2019). In other words, increased saliency may help learners focus their attention on and hold in memory a word that needs to be retained.

Movement has been shown to enhance word saliency and learning. Gestures (e.g., fine motor movements) are impactful in word learning and aid in the development of spoken vocabulary for children with DS (Dimitrova et al., 2016; Ozcaliskan et al., 2017; Zampini & D'Odorico, 2011). Higher rates of unique referent gestures (i.e., pointing to new objects) are seen in young children in DS than in children who are typically developing or children with autism (Dimitrova et al., 2016), and these unique referent gestures can enter into their spoken vocabularies with extended time (Ozcaliskan et al., 2017). Gesture use reliably predicts later word production in children with DS; additionally, use of word-gesture combinations predicts later ability to combine words into phrases (Zampini & D'Odorico, 2011). Moreover, use of specific signs (e.g., baby signs, ASL signs) and not simply referent gestures predict spoken vocabulary size a year later for young children with DS (Ozcaliskan et al., 2016).

There has been growing interest in the use of gross motor movements for word learning. Aerobic physical activity significantly improves word learning in children who are typically developing (Mellor & Morini, 2023; Pruitt & Morini, 2021). Integrating physical activity into word learning of a foreign language also significantly and positively impacts vocabulary performance in typically developing children (Mavilidi et al., 2015; Toumpaniari et al., 2015).

Unfortunately, very little research exists that looks at physical activity's link to language in children with disabilities. A single-case design study found that speech-language instruction embedded in physical education classes was more effective for growing child vocabulary than speech-language instruction in a traditional (seated) setting for children with DS (Lund et al., 2020).

Because iconic gestures (e.g., baby signs and ASL) are more predictive of language growth than referent gestures in children with DS, the use of dance fits well into the theory of saliency for word learning. Dance achieves both saliency and relevance (integrating social interaction) by utilizing joint attention and joint action to a high level; words are attached to actions performed jointly by the instructor and peers. Additionally, qualitative research has revealed positive attributes of dance with individuals with disabilities, identifying positive social interactions and overall joy in participants (Nelson, 2015; Reinders et al., 2019). Improved memory and increased ability to follow directions were also reported after a 6-week dance program with an adult with DS (Reinders et al., 2015). Although word learning and dance have not been studied in combination within this population, the theory of saliency supports the use of movement to make words more salient and more easily learned (Wildt et al., 2019).

Executive functioning, engagement, and physical activity

In addition to oral vocabulary deficits, weaknesses in cognitive skills have been found in young children with DS (Danhauer et al., 2014). Children with DS often experience deficits in executive functioning, working memory, planning, and inhibitory control and require targeted intervention (Tungate & Conners, 2021). Improvements in cognitive skills improve cognition itself but also can improve multiple other skills in children with DS. In fact, research suggests that improving cognitive skills could lead to increasing language and vocabulary skills (Kristensen, 2022).

Physical activity, including dance, has been found to improve cognitive skills in young children. Movement itself builds balance. Improving balance has resulted in improvements in working memory, cognitive flexibility, and inhibitory control (Nejati, 2021). Participation in dance specifically helps to build proprioception and balance skills and has had positive impact on working memory (Lakes & Hoyt, 2004; Oppici et al., 2020; Rudd et al., 2021; Shen et al., 2020), inhibitory control (Lakes & Hoyt, 2004; Lakes et al., 2019; Rudd et al., 2021; Shen et al., 2020), attention (Cherriere et al., 2020; Majorek et al., 2004; Shen et al., 2020; Zach et al., 2015), cognitive flexibility (Begel et al., 2021; Shen et al., 2020), and planning (Manjunath & Telles, 2001). In young children with intellectual disabilities, dance-movement therapy reduced maladaptive behaviors, such as attention issues (Takahashi et al., 2023).

An additional factor pertinent to word learning and inclusion of dance movement is the construct of engagement, which is the amount of time a child appropriately interacts with the environment (McWilliam, 2008). If children are not actively engaged, they miss opportunities for learning (McWilliam, 2008). Overall engagement can be broken down into three sub-constructs: cognitive engagement, behavioral engagement, and social engagement (Philp & Duchesne, 2008). Cognitive engagement involves processes of executive functioning, including sustained attention and inhibition. Behavioral engagement involves the length of time a child is actively involved in a task. Dance requires children to sustain attention to a teacher's movements and to remain actively involved in the learning task. Social engagement involves how a child interacts with adults and peers during a task. All three sub-constructs can impact word-learning success (Zhang, 2022). Engagement strategies to enhance attention, time on task, and social interaction have been developed in the context of vocabulary interventions (e.g., shared book reading) and add further benefit to these interventions (Blewitt & Langan, 2016). Similarly, the use of physical movement as a strategy to enhance engagement may strengthen the impact of word-learning interventions.

Although, it is known that movement and gestures can improve word learning in some children, it is unknown whether gross motor movements, such as dance, could aid in saliency and improve both engagement and word learning in children with Down syndrome, who are known to struggle with vocabulary. Additionally, it is unclear whether executive functioning skills of children with DS might influence their response to word learning interventions. The objective of the study was to determine if dance-based language intervention impacts vocabulary and engagement in children with Down syndrome and examine how it compared to traditional intervention. The central hypothesis of this work is that language-based dance therapy (i.e., movement-based instruction) will (a) increase oral vocabularies of children with Down syndrome because of increased saliency, (b) lead to higher engagement than traditional therapy, and (c) that executive functioning skills will correlate with word-learning outcomes in children with DS. The study questions are:

1. Does adding dance movements during word learning instruction result in more words learned for children with Down Syndrome as compared to traditional, spoken-language only teaching?
2. Do children with DS engage more during dance-based language instruction than in traditional, spoken-language only teaching?
3. Are numbers of words learned correlated with executive functioning skills and does this correlation differ for session type?

Methods

Experimental Design

A randomized pre-test post-test crossover design was used to measure the effects of language-based dance intervention as compared to traditional speech-language intervention on word learning and session engagement. Crossover design studies are intended to use participants as their own control, which reduces interindividual variability (Aggarwal & Ranganathan, 2019). This design was selected because high power and statistical significance can be achieved even with a small number of participants (Senn, 2002; Wellek & Blettner, 2012). In traditional crossover design studies, participants are randomized then placed into treatment sequences; participants in the first sequence (AB) would receive intervention 1 in the first period (A) followed by intervention two in the second period (B) and vice versa for the second sequence (BA). In the current study, participants received the speech-language intervention for all 12 weeks; half of the participants received the dance intervention for the first 6 weeks, and the other half received the dance intervention for the second 6 weeks.

Participants and Setting

All procedures in this study were approved by the Texas Christian University Institutional Review Board. Participants included 21 children: 16 had Down syndrome, 4 had typical development, and 1 had Williams syndrome. All children were students from a university lab preschool for children with developmental delays. Consent forms were sent home with all students in the oldest two preschool classes, and all consent forms were returned. Children were between the ages of 33 and 72 months at the start of the study and used English as the primary language of instruction. The variation in age range and in diagnosis is managed by the research design: a cross-over design allows for strong within-subject controls. All children had basic mobility skills, allowing them to fully participate in the dance intervention movements. See Table 1 for descriptive information for all participants.

Table 1. Descriptive information and assessments (means and standard deviations) by group.

	Down Syndrome	Typically-Developing	Williams Syndrome
Gender	Male: 7 Female: 9	Male: 2 Female: 2	Female: 1
Age (in months)	54.31 (11.1)	43.50 (9.61)	40.00
Race	Black: 1 White: 15	White: 4	*
Ethnicity	Hispanic/Latino: 4 Non-Hispanic: 9 No Response: 3	Non-Hispanic: 2 No Response: 2	*
Maternal Education	Some college: 1 Associates: 2 Bachelors: 3 Some graduate: 1 Masters: 6 No Response: 3	Some college: 1 Masters: 2 No Response: 1	*
Peabody Picture Vocabulary Test-5	60.77 (19.63)	122 (6.08)	*
Expressive Vocabulary Test-4	47 (28)	124 (21)	*

Note. * indicates information not provided due to concerns about identifiability of child included in this group.

All children except for three of the typically developing participants were administered the Leiter International Performance Scale–Third Edition (Roid et al., 2013). The Leiter has alpha reliability coefficients above .80 for each subtest for this age group (Roid et al., 2013) and has been validated for capturing a range of nonverbal intelligence scores in children with Down syndrome (Liogier d'Ardhuy et al., 2015). The Expressive Vocabulary Test-Second Edition (EVT-2; Williams, 2007) was administered to assess expressive vocabulary skills. The EVT-2 has reliability coefficients between .83 and .91 and reported good construct and concurrent validity, although scores for children with speech-language deficits vary widely (Williams, 2007). The Peabody Picture Vocabulary Test-Fifth Edition (PPVT-5; Dunn, 2019) assessed receptive vocabulary; it has good to excellent reliability correlations (.85 to .88) average to excellent correlation (.46-.75) shown through correlations with other measures and clinical validity studies with special populations (Pearson Education, 2018). Preschool classroom teachers completed the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P; Gioia et al., 2003), a teacher report of executive-functioning skills. The BRIEF-P teacher report has alpha reliability coefficients above .75 for each subscale for children with Down Syndrome (Esbensen et al., 2019) and has established good concurrent and convergent validity for all three indices (Inhibitory Self-Control, Flexibility, and Emergent Metacognition) in children with Down syndrome (Liogier d'Ardhuy et al., 2015; Pritchard et al., 2015).

Children attended the preschool 5 days per week, 7.5 hours each day. The classroom was taught by a master's-level early childhood special education teacher and two teaching assistants with associate degrees in child development. In addition to instruction in the classroom related to academic and social-emotional development, all students received adapted physical education 5 days per week, speech therapy (group and individual) 2-3 days per week, physical therapy consultation 1 day per week, music therapy 1 day per week, and individual occupational therapy 2 times per month. In their free time, the participants were involved in a range of physical activities, including outside dance classes for children with special needs.

Development of Experimental Measures

Words for Probe Assessment and Intervention. The words included in the dance and traditional language interventions were developed from an existing corpus of words used in other preschool word-learning studies (e.g., Lund & Douglas, 2016). Intervention word lists were formulated by the first author, who created 7 lists of 10 words each--2 lists for the dance intervention, 4 lists for the traditional intervention, and 1 control list. Lists were balanced by word age of acquisition, phonotactic probability, and frequency and contained the same number and type of words (three nouns, five verbs, and two prepositions). A team of three licensed SLPs, including the treating clinicians, judged the words for inclusion by indicating whether children with DS were likely to already know this word and whether the word was appropriate for a child in that age range. All SLPs voted yes to include the word as a target on one of the word lists. Each word was represented by a clipart-quality picture card with a white background. Four school-aged children confirmed that each picture represented the target word by naming the object or picture correctly. See Table 2 for word lists.

Table 2. Words targeted by intervention type and schedule.

	List 1: Dance (Sessions 1-6; Three weeks)	List 2: Dance (Sessions 7-12; Three weeks)	List 3: Speech (Weeks 1-3)	List 4: Speech (Weeks 4-6)	List 5: Speech (Weeks 7-10)	List 6: Speech (Weeks 11-12)	List 7: Control
Nouns	Butterfly	Chin	Box	Boots	Carrot	Arm	Squirrel
	Snail	Kangaroo	Finger	Hippo	Elbow	Balloon	Walrus
	Toes	Knee	Rooster	Forehead	Goose	Mouse	Wrist
Verbs	Climb	Catch	Come	Bite	Build	Choose	Bounce
	Fly	Hop	Give	Carry	Laugh	Clean	Chase
	Hide	Point	Knock	Draw	Leave	Drive	Paint
	Kiss	Spin	Make	Dress	Smile	Hold	Pour
	Reach	Throw	Scoop	Ride	Zip	Start	Swim
Prepositions	Below	Behind	In(to)	Beside	Around	Out(side)	Across
	(On)Top	Under	Over	Front	Between	Through	After

Engagement Rating. The engagement assessment was developed using a previously developed assessment method from the Child Hearing, Language, Literacy and Deafness (CHLLD) Lab at Texas Christian University. In previous studies (e.g., Ridings, 2020), engagement was measured via an engagement rating scale (perceived social engagement during the tasks). The engagement rating scale, developed from a review on engagement literature, rated overall interactions through gestures, commenting, and establishment of joint attention with the examiner/instructor, using a 5-point scale. A 1 represented no engagement and need for constant redirections, and a 5 represented independent engagement and no redirections to task. For this study, a second version of the engagement rating scale was developed to reflect expected behaviors in a dance session. Two trained observers rated participant engagement during week 3 of intervention and determined time-on-task by using a stopwatch to record the amount of time a student was exhibiting on-task behaviors during the session (resulting in a percentage). See Appendix A for engagement scales.

Procedures

Probe assessment. Probe assessments are proximal measures of child knowledge acquisition (Kennedy, 2005). The assessment, created by the authors, tests child knowledge of vocabulary targets via clipart-quality picture cards presented digitally. Participant responses were recorded as "word" if they labeled the item, "approximation" if they gave a verbal approximation, "gesture" if they gave an appropriate sign or gesture, or "none" if the response was incorrect or not attempted. The examiner did not provide any feedback as to whether the child's response was correct. Every three weeks participants were assessed with the word list probes. In order to lessen test fatigue, only word lists that were targeted or soon to be targeted were included in the probe. See table 3 for which word lists were included during each probe. Probe assessments were administered individually by one of the authors in a quiet area of the classroom and lasted around 5-10 minutes, depending on the child.

Table 3. Schedule for crossover of intervention types.

	Before Week 1	Weeks 1-3	End of Week 3	Weeks 4-6	End of Week 6	Weeks 7-9	End of Week 9	Weeks 10-12	End of Week 12
Group A	Vocabulary Probe *(word lists 1, 2, 3, 4, and 7)*	Traditional *(target list 3)* & Dance *(target list 1)*	Vocabulary Probe *(word lists 1, 3, and 7)* Engagement Scale	Traditional *(target list 4)* & Dance *(target list 2)*	Vocabulary Probe *(all word lists)*	Traditional *(target list 5)*	Vocabulary Probe *(word lists 1, 5, and 7)*	Traditional *(target list 6)*	Vocabulary Probe *(all word lists)*
Group B	Vocabulary Probe *(word lists 1, 2, 3, 4, and 7)*	Traditional *(target list 3)*	Vocabulary Probe *(word lists 1, 3, and 7)*	Traditional *(target list 4)*	Vocabulary Probe *(all word lists)*	Traditional *(target list 3)* & Dance *(target list 1)*	Vocabulary Probe *(word lists 1, 5, and 7)* Engagement Scale	Traditional *(target list 6)* & Dance *(target list 2)*	Vocabulary Probe *(all word lists)*

Traditional intervention. Each child participated in their regularly scheduled traditional speech-language intervention for 2-3 days of the school week across 12 weeks total. Each child received at least one 30-minute large group (10-11 children) and one 30-minute small group (2 children) speech-language session weekly. Every other week, they also received an individual session. During the weekly sessions, the second author, who is a certified and licensed speech-language pathologist, targeted individual goals using the study words for that 3-week period via traditional, evidence-based techniques (business as usual for speech-language services in this preschool). She utilized the classroom video projection for visuals and manipulatives, such as toys. She paired each target word with appropriate gesture/sign. Dance and gross motor movements were not used during traditional therapy sessions. Staff support (i.e., classroom teacher and 2 aides) was provided for the group sessions.

Dance intervention. Dance intervention consisted of two weekly 20-minute language-based dance classes, lasting six weeks (i.e., 12 sessions total). This dosage and frequency are based on intervention for word learning with children who have Developmental Language Disorder, which suggests 36 exposures needed for a target word (Storkel et al., 2019). Each session provided at least 6 exposures to the target word, with the first 3 weeks targeting 10 words (list 1) and the last 3 weeks targeting a new 10 words (list 2). List 1 words were reinforced during weeks 4-6. See Table 3 for intervention rounds. Each session had 5-6 children with support from 2 undergraduate students and 1 school aide. The focus of intervention was to teach vocabulary via paired movement (e.g., "spin" paired with turning movement). The first author, who is a certified and licensed speech-language pathologist as well as trained dancer, spoke the word showing accompanying gesture/sign. She then modeled the movement while saying the target word. Participants were then prompted to imitate the word and movement at least 6x each session. Each session started with a "hello" song to transition the students to the dance area (no words were targeted). There were two exercise sets that focused on teaching the target words and two exercise sets used to reinforce the target words. A "goodbye" song reviewing words from the session closed the dance session. Instrumental music was used during the teaching exercises. Commercially available children's music with lyrics was used during the reinforcing exercises. All music was at a low volume, allowing the voice of the clinician to be easily heard. Lyrics from the music were not taught, allowing the focus to be on the words of the clinician. For prepositional concepts, manipulatives including scarves and beanbags were used. See Appendix B for a sample of the Dance Intervention Lesson Plan.

Procedural fidelity. Every dance intervention session was video recorded to monitor intervention fidelity. The interventionist's adherence to script and modeling of vocabulary and movement was assessed by a trained observer, who was an undergraduate student and assisted in the sessions. Fidelity assessments for 25% of the dance intervention sessions found that the interventionist followed the procedure with 100% fidelity.

Results

The objective of the study was to determine if language-based dance therapy improves word learning and engagement in children with Down syndrome more than traditional intervention. The dependent variable in this study for comparing the intervention conditions was the change in number of correctly labeled vocabulary items between the pre-intervention and post-intervention probe assessment, later referred to as "words gained."

All 21 participants had completed pre-intervention and post-intervention word list probes, BRIEF-P teacher reports, and engagement surveys. One participant with DS was unable to complete standardized testing (i.e., PPVT-5, EVT-2, and Leiter), and one participant who was TD did not complete standardized testing due to absences. Only one participant that was TD completed the Leiter; the three other participants who were TD did not complete it due to time constraints. All participants attended at least 8 out of the 12 dance intervention sessions.

The first research question asked if adding dance movements during word learning instruction results in more words learned for children with Down syndrome as compared to traditional, spoken-language only teaching. A repeated measures ANOVA was run to determine if there was a significant difference between number of words learned in the dance intervention versus the traditional intervention. Data was not normally distributed for the dance word gains and control word gains, as assessed by the Shapiro-Wilk test of normality. There were three outliers but only for the control words condition. Due to the assumption of sphericity was violated, as assessed by Mauchly's test of sphericity ($p< .05$), the Greenhouse-Geisser correction was used. Data are mean ±standard deviation, unless otherwise stated. For the main effect of intervention type the Greenhouse–Geisser estimate of the departure from sphericity was $\varepsilon = 0.67$. The main effect was significant, F (1.34, 26.78) = 19.71, p = <.001, partial η^2=.496. Contrasts revealed that word gain in the dance intervention were significantly higher than traditional intervention, F (1, 20) = 19.07, p <.001, partial η^2=.488. These findings had a large effect size (r= .7). Descriptive statistics showed that all children gained an average of 4.05±3.28 words in the dance intervention and .71±1.49 words in the traditional intervention. Children learned an average of .33±1.24 of the control words. Children with DS gained an average of 3.94±3.59 words in the dance intervention, 0.37±1.26 words in the traditional intervention, and 0.25±1.18 of the control words. See Figure 1 for descriptive data.

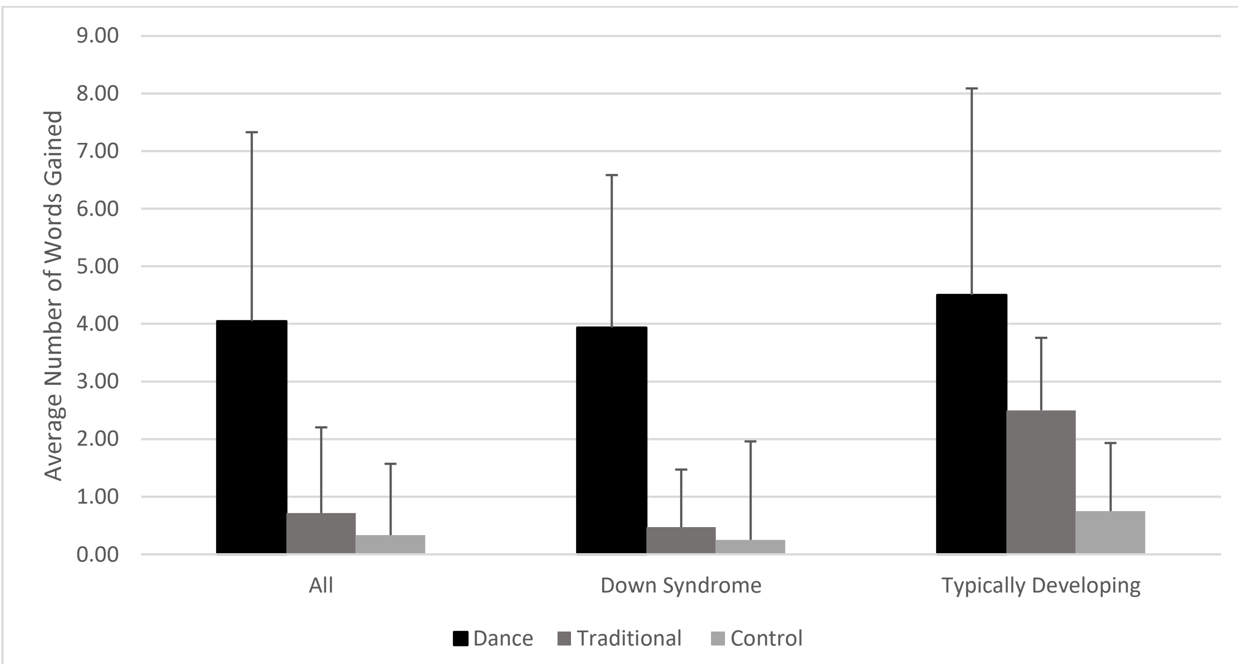

Figure 1. Words gained during intervention types by group. Error bars reflect standard deviations.

For the second question, do children with DS engage more in dance-based language instruction than in traditional, spoken-language only teaching, paired samples t-tests were conducted to compare participants' intervention engagement scores. The assumption of normality was not met for engagement scores, so the Wilcoxon signed rank test was used. Engagement during intervention sessions were not statistically different (z = -.258, p = .796).

Average ratings for engagement in a dance session was 2.58 (±.902) while average ratings for engagement in a traditional session was 2.53 (±1.07). Assumptions were met for time on task data, and a paired samples *t*-test was run. Findings were also not statistically different (t = -.74, p = .234), with time on task during dance intervention being an average of 78% of the session and during traditional interventions being on task an average of 80% of the session.

The third question asked if numbers of words learned correlated with executive functioning skills and if the correlation differs for session type. All assumptions for Pearson correlations were met and run for this question. First, we evaluated words gained and correlation to the BRIEF-P Global Executive Composite score; higher BRIEF scores mean more difficulty with executive functioning skills. The BRIEF-P Composite score was significantly negatively related to word gain in traditional intervention (r=-.46, p=.04) but was not significantly related to word gain in the dance intervention (r=.26, p=.25). Upon further analysis of the BRIEF-P's sub-areas, words gained in traditional intervention significantly correlated with working memory (r=-.52, p=.02) and the Emergent Metacognition Index (r=-.47, p=.03). See Table 4 for correlations.

Table 4. Correlations between Words Gained and the BRIEF-P composite, index, and subtest scores (Pearson's r and p-value)

	Global Executive Composite	Inhibitory Self Control Index	Flexibility Index	Emergent Metacognition Index	Inhibit	Shift	Emotional Control	Working Memory	Plan/ Organize
Dance Intervention Words Gained	.26 (.251)	.30 (.182)	.16 (.484)	.17 (.475)	.36 (.105)	.08 (.725)	.21 (.361)	.15 (.521)	.18 (.440)
Traditional Intervention Words Gained	-.46* (.036)	-.32 (.154)	-.31 (.168)	-.47* (.032)	-.29 (.208)	-.27 (.233)	-.31 (.167)	-.52* (.016)	-.34 (135)

Note. *p < .05; BRIEF-P=Behavior Rating Inventory of Executive Function-Preschool (Gioia, et al., 2003).

Discussion

The purpose of this study was to evaluate the effect of using movement (i.e., dance) to enhance word-learning outcomes of preschool children with Down syndrome. Significantly more words were gained from the dance intervention than traditional intervention for all children in the study regardless of disability status. Engagement ratings and time on task were not significantly different between intervention types. Teacher ratings of executive functioning skills were not significantly correlated with words gained during dance intervention but were significantly correlated with words gained during traditional intervention.

Word Learning

The word learning of the children in this study was consistent with past studies of vocabulary in children with Down syndrome (e.g., Warren et al., 2008; Yoder & Warren, 2004). Children with DS showed the ability to learn words, but at a slower rate than their peers with typical development. All but three children in this study demonstrated an increase in oral vocabulary of words targeted over the course of six weeks. All three of these children were primarily non-verbal communicators, with one using sign language as his primary communication modality. These three children did not demonstrate word gain in either intervention, but two showed positive gains in use of gesture/sign for the targeted words with both signing more target words from the dance intervention.

Similar to findings from word learning and movement studies with typically developing children (Mavilidi et al., 2015; Toumpaniari et al., 2015), movement aided learning of words for children with and without DS. Out of the 18 children who showed word gain, 16 of them learned more words in the dance intervention than in the traditional intervention. For the remaining two children, they gained the same number of words in both interventions. The maximum number of words learned by a child with DS from the dance intervention was ten, whereas the maximum from the traditional intervention was three. These findings support the use of movement in speech-language interventions and encourage future research into the best use of movement in intervention.

Engagement

Studies have found a positive impact of physical activity on school engagement (Owen et al., 2016); however, few studies have compared active engagement during physical activity and non-active tasks. We hypothesized that there would be a difference between engagement during the dance intervention and engagement during the traditional intervention; however, no differences were found in terms of engagement during interventions. Children, regardless of disability status, had very similar ratings of engagement and percentage of time on task for both interventions. This may have been influenced by three possible factors: (a) familiarity with the traditional intervention behavior expectations, (b) timing of traditional intervention sessions, and (c) design of engagement scale.

The first factor was the students' familiarity with the traditional intervention behavior expectations. Most of the students had been at the preschool for over a year, and they were familiar with the SLP leading the traditional interventions. Behavior expectations such as sitting in an assigned spot, looking at teacher, and commenting when prompted/expected to were elements embedded in the engagement scale and behaviors that had already been targeted. In comparison, the SLP leading the dance intervention was new to the students and the expected behaviors were also novel.

The second potential factor was the timing of the traditional intervention sessions. While the dance intervention sessions took place during the classes' physical education time, the traditional intervention sessions took place after the physical education time. Research suggests that physical activity can aid in attention during school-based lessons (Schmidt et al., 2015; Tine

& Butler, 2012). By having a physical education lesson prior to a traditional speech-language session, the participants may have had increased attention.

The third potential factor is the design of the engagement scale itself. Both raters of the engagement survey made comments that the scale was not specific enough to each skill; several students fell between ratings because they demonstrated certain signs of engagement but not others. Adaptations to the scale may provide a better picture of the participants' engagement. The scale was originally designed to capture engagement in seated tasks for children who are deaf and hard of hearing (Ridings et al., 2020) and it is likely that it needs to be adapted for task type. It is, however, possible that students did not experience different engagement across task types and that a dance-based intervention does not result in improvements because of an increase in engagement. In that case, improved performance would be related to other factors associated with dance-based instruction.

Executive functioning and movement

With the knowledge that movement, specifically dance, can improve executive functioning skills (e.g., Cherriere et al., 2020; Rudd et al., 2021; Shen et al., 2020), the current study sought to evaluate the correlations between words gained in each intervention and executive functioning skills. Although executive functioning skills were not correlated with words gained in the dance intervention, executive functioning skills were correlated with words gained in the traditional intervention, especially working memory. This data seems to suggest that to make gains in traditional intervention, foundational executive functioning skills, such as working memory, are required; whereas, adding movement via dance made word learning accessible to even those children who struggled with executive functioning. Because dance has also been shown to improve working memory in children (Lakes & Hoyt, 2004; Oppici et al., 2020; Rudd et al., 2021; Shen et al., 2020), it may be an effective tool in both aiding word learning and improving working memory, which supports Kristensen's (2022) suggestion that improving cognitive skills could lead to increasing language and vocabulary skills in children with DS.

Saliency

Saliency is an important part of vocabulary instruction (Pruden et al., 2006; Wildt et al., 2019). This study aimed to evaluate how using dance-based movements during intervention could add saliency to vocabulary in children with DS. The results from this study show that dance-based vocabulary instruction resulted in stronger word gains not only for children with DS but for the majority of children in the study regardless of diagnosis. Although this increased saliency through movement was not found to increase engagement (e.g., an observational measure of focused attention), the saliency gained through dance does seem to facilitate word-leaning even when there are working memory deficits. Traditional interventions appear to depend on working memory, but that does not appear to be a requirement when a word becomes more salient through movement. This means that adding saliency in word-learning interventions is of great importance to children with DS, and dance-based movement is an effective way to add saliency.

Limitations and Future Directions

This study provides avenues for future study of the use of gross motor movement to enhance traditional interventions for word learning in children with DS. A limitation of this study is that it was not a true crossover design; traditional speech-language intervention was provided throughout the entirety of the 12 weeks, and there was not a washout period between switching groups (Lim & In, 2021). Although randomization occurred at a class-based level, full randomization as expected in crossover design was not possible. Each class had to be randomized individually due to physical education classes taking place at different times and the availability of staff support. Although this preliminary study provides excellent support for the use of movement/dance in speech-language intervention, true crossover design would allow for a cleaner, direct comparison. A second, related limitation is that the traditional intervention was not as protocol-based as the dance intervention. Although the word lists were agreed upon and matched for difficulty, the intervention methods were not matched. There were fidelity checks for the dance intervention, ensuring that each word was presented at least 6x per session; however, the same fidelity checks were not completed for traditional intervention. Although this is a study weakness, this is extremely reflective of what happens in preschools nationwide, which may mean that the data is very generalizable to real-world situations. Even so, future research might consider a similar study using true crossover design with protocols for both intervention types, ensuring that equal presentation of words occur. Similar controls for session time (e.g., consistently before or after physical education class) and familiarity with interventionist could aid in measuring engagement.

Future directions could also include children of higher ages and differing diagnoses. There was 1 participant in this study who had Williams syndrome. This child had results very similar to her peers, showing more words gained from the dance intervention. This data shows promise for using similar movement interventions with preschool-aged children of differing diagnoses. There were also no significant differences found between ages or IQ-levels, meaning similar results may be found for children in older grades or of varying ability levels.

Given the interesting finding regarding executive functioning correlations with intervention types, measuring growth of executive functioning through intervention is an additional future direction. Physical activity, specifically dance, has been found to support gains in executive functioning (Nejati, 2021; Shen, 2020). Structured dance lessons have resulted in positive gains in working memory (Lakes & Hoyt, 2004; Oppici et al., 2020; Rudd et al., 2021; Shen et al., 2020), inhibitory control (Lakes et al., 2019; Lakes & Hoyt, 2004; Rudd et al., 2021; Shen et al., 2020), attention (Cherriere et al., 2020; Majorek et al., 2004; Shen et al., 2020; Zach et al., 2015), cognitive flexibility (Begel, et al., 2021; Shen, et al., 2020), and planning (Manjunath & Telles, 2001). It would be useful to measure the growth in executive functioning skills, especially working memory, in children with DS when participating in physical activities such as dance. If dance not only allows for learning to occur in individuals with low executive functioning skills but also builds executive functioning skills opening the door to other intervention methods, it would be beneficial to build more inclusive opportunities for children with DS.

Conclusion

Overall, this study provides knowledge that adding movement to word-learning intervention can significantly affect word gains made by all children, particularly those with Down syndrome. Dance-based intervention resulted in significantly more words gained in 6 weeks than traditional speech-language intervention. Engagement and time on task for children with DS did not significantly differ between intervention types. Whereas word gain during traditional intervention correlated with higher executive functioning skills, word gain during the dance-based intervention did not correlate with executive functioning skills. These findings encourage the use of gross motor movement to enhance saliency in word learning for preschoolers with Down syndrome, especially those that may have limited working memory skills.

Acknowledgements

This work was funded by a student research grant from Harris College of Nursing and Health Sciences at Texas Christian University. The contributions of the preschool faculty and staff as well as the research lab's study team are gratefully acknowledged.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

CHAPTER IV: Etiology Differences and the Effects of Physical Activity and Executive Functioning on Language Development

Abstract

Purpose: The purpose of this study was to evaluate the role of physical activity in language and executive functioning development in children with secondary language disorders and to compare the differences in the domain relationships according to disability type.

Method: This study included 75 monolingual children between the ages of 7 and 18: 25 children who were deaf and hard of hearing, 25 children with Down syndrome, and 25 children with no biomedical diagnosis. Parents of children in each group completed a report on deficits in executive functioning (the Behavior Rating Inventory of Executive Function-Second Edition) and a questionnaire regarding participation in physical activities; the children participated in performance-based measures of language (the Clinical Evaluation of Language Fundamentals-Fifth Edition) and executive functioning (NIH Toolbox Cognition Battery).

Results: Analyses revealed that etiology substantially impacted the relation between the three domains: children with Down syndrome have clinically significantly lower participation in structured physical activities as well as statistically significant lower language and executive functioning skills than children who are deaf and hard of hearing and children with typical development. Executive functioning significantly predicted language outcomes for all children, especially when variability in language scores due to differences among groups was accounted for. Further, participation in physical activities interacted with executive functioning skills to predict language skills. Significant group-based differences were found in the executive functioning and language domains, with children with Down syndrome having more reported difficulties with executive functioning and lower language scores than children who are typically developing and children who are deaf and hard of hearing. Executive functioning scores significantly predicted language, especially when accounting for the variability in language

scores due to differences among groups. Further, participation in structured physical activity moderated the effect of executive functioning on language skills.

Conclusion: This study supports the idea that children develop as dynamic systems, and it represents a first step in identifying how participation in motor activities relates to language and executive functioning development in children with special needs because no single domain develops in a vacuum (i.e., there are internal and external relationships at play). These findings have implications for differentiated language interventions according to disability type and the incorporation of additional domains.

Introduction

In recent years, there has been increased interest in how physical activity can support executive functioning development in children (Bidzan-Bluma & Lipowska, 2018; Sibley & Etnier, 2003; Zeng et al., 2017). Studies suggest a link between physical activity and cognition, especially if the activity is aerobic in nature (Best et al., 2010; Chaddock et al., 2011; Fedewa & Ahn, 2011). Additionally, language scientists have been exploring the connection between physical activity and word learning, a verbal behavior that involves non-verbal cognition (Mellor & Morini, 2023; Pruitt & Morini, 2021; Toumpaniari et al., 2015). However, research has not yet defined a clear connection between all three domains: physical activity, non-verbal cognition, and language in children. Of particular note is the general exclusion of children with disabilities in studies evaluating the relationship between two of the domains; these studies often exclude children with speech-language impairments, intellectual disabilities, and other disorders. Children with language disorders can have difficulty with language skills, including vocabulary (Lund, 2016; Zampini & D'Odorico, 2013), syntax (Frizelle et al., 2018; Werfel et al., 2021), morphology (Eadie et al., 2002; Moeller et al., 2010), and pragmatics (Most et al., 2010; Smith et al., 2017). Literacy is linked to language and cognitive skills; for example, children with disabilities can experience delays in phonological awareness (Fletcher & Buckley, 2002; Lund, 2020), reading accuracy (Naess et al., 2012; Werfel et al., 2015), and comprehension (Asker-Árnason et al., 2015; Laws et al., 2016). Thus, children with disabilities may be at a profound disadvantage for both academic and social success (Mann et al., 2017). As children age into adulthood, the effects of these deficits continue, having lasting impact on quality of life (Ching et al., 2021). If physical activity is influential in the development of language and cognition for children who are typically developing, it may also be impactful for children with disabilities.

Therefore, it is important to understand how participation in physical activities relates to linguistic and cognitive development in children with disabilities and how different disability profiles may impact the interaction between physical activity and development. The purpose of this study was to evaluate the role of physical activity in language and executive functioning development in children with diagnoses associated with secondary language disorders and to compare the differences in the domain relationships according to disability type.

Executive Functioning and Language

Cognition can be defined as a person's awareness and knowledge and includes abilities such as perception, memory, judgment, and reasoning (American Psychological Association, 2018). Cognitive control, also known as executive functioning skills, are the effortful, higher-level skills that allow us to engage in the behaviors required to achieve goals, such as learning (Anderson, 2002). , Executive functioning is separate from but related to language skills (Kaczmarek et al., 2018; Sikora et al., 2019). Executive functioning includes inhibition, working memory, mental flexibility, controlled attention, self-monitoring, organization, and goal direction. Both language skills and executive functioning predict academic and social success, impacting a child's overall quality of life (Blair & Raver, 2015; Clark et al., 2013; McClelland et al., 2013). Executive functioning appears to influence overall and language development from a young age (Danhauer, 2014; Kapa & Erikson, 2019; Marini et al., 2020). Measures of working memory and inhibitory control have been found to be direct predictors of academic readiness and indirect predictors of social-emotional readiness (Mann et al., 2017). As a child ages, the influence of executive functioning on academic outcomes increases. Executive functioning skills are among the main predictors of academic achievement during- and post- middle school (Samuels et al., 2016).

Executive functioning and language develop concurrently, and executive functioning abilities have been found to aid language development (Weiland et al., 2014). The relationship may be bi-directional, as language also opens the door to more complex executive functioning skills. This relationship reflects executive functioning's role with learning–executive functioning skills control both actions and thoughts which are required for learning to occur (Anthony & Ogg, 2020; Garner, 2009). Because executive functioning skills can act as a prerequisite for overall learning by helping a child be able to attend, shift between tasks, and inhibit off-task behaviors, language learning can also be impacted by these same executive functioning skills. In fact, research suggests that improving executive functioning skills can lead to increasing language skills for children with Down syndrome (Kristensen et al., 2022). Similar gains in language as a result of executive functioning increases could also occur for children with varying language disorder etiologies.

Etiology Variances in Executive Functioning

Deficits in executive functioning have been identified and evaluated in samples of children with disabilities. Although many children with language disorders, regardless of etiology, have identified deficits in both language and executive functioning, executive functioning skills appear to vary dependent on the type and severity of disability. The effects of disability etiologies on executive functioning skills can be clearly seen by comparing three distinct groups: children who are typically developing (i.e., no diagnosis of a medical disability/disorder), children with diagnoses related to global delay and inclusive of intellectual disability (e.g., Down syndrome), and children with diagnoses related to other issues (e.g., sensory issues like hearing loss) and without intellectual disability. Each of these groups can include individuals with a range of overall and linguistic outcomes, but expected executive functioning skills differ.

Global Delay. Children with global delay, including those with intellectual disabilities, such as Down syndrome (DS), exhibit executive functioning deficits which are a part of the global delay (generally inclusive of intellectual disability) impacting all learning. As children with intellectual disability age, executive function deficits, such as difficulty with inhibition, initiation, working memory, task monitoring, planning, organization, and attentional shift grow (Loveall et al., 2017). Children with DS often struggle with foundational executive functioning skills which prepare a child to learn. Children with DS exhibit difficulty with working memory, planning, and inhibitory control (Daunhauer et al., 2014; Daunhauer et al., 2017). These executive functioning deficits, including attention, follow individuals with DS into adulthood (Grieco, 2015).

Deaf and Hard of Hearing. For children whose primary impairment is hearing loss and do not have co-occurring intellectual disability, experiencing developmental challenges as a result of a sensory deficit rather than overall functioning delays, deficits in executive functioning skills are primarily moderated by access to language, rather than their innate language-learning abilities (Hall et al., 2018). Children who are deaf and hard of hearing (DHH) may experience language delays as the result of degraded auditory input (Nittrouer et al., 2022) or lack of language access (Hall at al., 2018). Children who are DHH, regardless of type of amplification (i.e. cochlear implant or hearing aid), often have difficulties with speech recognition, vocabulary, nonword repetition (associated with working memory), and literacy which persist as they age (Lund, 2016; Nittrouer et al., 2018; Pisoni et al., 2011; Werfel, 2017). Because the development of executive functioning is believed to be influenced by early auditory pathway experience and activity, difficulties with executive functioning, including verbal working memory, fluency-speed, and inhibition-concentration have been identified in children who are DHH and use cochlear implants even in those children who have language development that falls in the range of normal on standardized measures (Kronenberger et al., 2020; Kronenberger et al., 2018; Kronenberger et al., 2013). However, research with Deaf children who have access to sign language from birth suggests that executive functioning skills are not dependent on auditory access but instead on language access; Deaf children who have access to sign language from birth are not significantly different from typically developing peers on parent-report measures of executive functioning (Hall et al., 2018). On performance-based measures of executive functioning skills, children who are DHH and use cochlear implants score more poorly than their typically hearing peers but comparable to norms; and on parent checklists, children who are deaf and hard of hearing score more poorly than their typically hearing peers on measures of inhibition and working memory (Kronenberger et al., 2020). In a recent study comparing attention-deficit behaviors in children who are DHH and their typically hearing peers, parents of children who use hearing aids reported more attention-deficit behaviors than parents of children who use cochlear implants and parents of children with typical hearing (Mattingly et al., 2023).

A unique difficulty for children who are deaf and hard of hearing, aside from difficulty with language development, can be listening fatigue. Listening fatigue is a type of cognitive fatigue, which is characterized by difficulties in concentration, increased distractibility, anxiety, inattention, and decreases in mental energy and efficiency (Boksem & Tops 2008; Lieberman, 2007). Increased risk for listening fatigue may occur in children who are DHH due to executive functioning issues such as verbal working memory deficits (Camarata et al., 2018; Nittrouer et al., 2017). Measures of fatigue are correlated with attention deficit behaviors in children with hearing loss; the greater the listener fatigue, the greater reporting of attention deficit behaviors (Mattingly et al., 2023).

Given that the executive functioning profiles of children with disabilities differ from children without disabilities, it is important that these children are included in studies evaluating the relationships between executive functioning, language, and any other domains. Although studies of executive functioning in children who do not have additional diagnoses inform scientific understanding of these skills, findings of those studies cannot be generalized to children with disabilities. Arguably, it is particularly important to understand relations between executive functioning, language, and other domains in populations with disabilities because that knowledge will underlie future efforts to improve executive functioning (and language).

Physical Activity and Executive Functioning

High levels of physical activity are linked to better executive functioning and language outcomes than low levels of physical activity (Carson et al., 2016; Erickson et al., 2019). Children who are more physically active have better behaviorally-measured attention and memory skills than children who are sedentary (Cadenas-Sanchez et al., 2023; Shao et al., 2022; Sibley & Etnier, 2003). Both acute and chronic engagement in physical activity have been found to have positive effects on executive functioning (Best, 2010). This may be because executive functioning and proprioceptive performance (i.e., awareness of where one's body is in space) are strongly related in childhood (Gordon-Murer et al., 2021). Good proprioception results in better balance and motor control and requires fewer attentional resources (Česnaitienė et al., 2022). Movement itself also builds balance. Improving balance has resulted in improvements in working memory, cognitive flexibility, and inhibitory control (Nejati, 2021). The relationship may be bidirectional—in a study with healthy adults, executive functioning training correlated with improvements in balance (Li et al., 2010). Participation in physical activities which build proprioception and balance skills have had positive impact on working memory (Lakes & Hoyt, 2004; Oppici et al., 2020; Rudd et al., 2021; Shen et al., 2020), inhibitory control (Lakes & Hoyt, 2004; Lakes et al., 2019; Rudd et al., 2021; Shen et al., 2020), attention (Cherriere et al., 2020; Majorek et al., 2004; Shen et al., 2020; Zach et al., 2015), cognitive flexibility (Begel et al., 2021; Shen et al., 2020), and planning (Manjunath & Telles, 2001).

Physical Activity and Language

Though there have been fewer studies on physical activity linking to improvements in language skills, there is a limited amount of research supporting the hypothesis that more physical activity may result in better language outcomes (Carson et al., 2016). Of note, aerobic physical activity was found to significantly improve word learning in children who are typically developing (i.e., do not have other disabilities diagnosed; Mellor & Morini, 2023; Pruitt & Morini, 2021). Integrating physical activity into word learning of a foreign language also significantly and positively impacts vocabulary performance in typically developing children (Mavilidi et al., 2015; Toumpaniari et al., 2015). Very little research exists that looks at physical activity’s link to language in children with disabilities. A pilot group-design study with children with Down Syndrome utilized movement to teach vocabulary; the movement-based intervention resulted in better word learning than traditional speech-language intervention techniques (Mattingly et al., submitted). Another single-case design study found that speech-language instruction embedded in physical education classes was more effective for growing child vocabulary than speech-language instruction in a traditional (seated) setting (Lund, et al., 2020). Additionally, physical activity has been shown to enhance word learning in both typically developing children and children who are DHH; children who are DHH benefited most from general physical activity (i.e., jumping jacks) whereas children who are typically developing benefited most from semantically rich physical activity (i.e., iconic yoga poses; Werfel & Lund, 2024). These findings suggest that physical activity may positively impact language development.

Etiology Variances in Participation in Physical Activity

According to the 2021 national Youth Risk Behavior Survey, less than 24% of children in the United States meet the requirement of at least 60 minutes daily of physical activity suggested by the physical activity guidelines (Centers for Disease Control and Prevention, n.d.). Children with disabilities are reportedly 4.5 times less active than their typically developing peers (Rimmer, 2008). Participation in physical activity is often lower for children with disabilities, likely as a result of external, systemic barriers to structured physical activity opportunities (e.g., organized sports; Rimmer, 2008). Adults with disabilities report that many environmental barriers exist which result in decreased physical activity participation including cost, transportation, lack of accessible equipment, and unqualified staff (Rimmer et al., 2004). Additionally, children with secondary language disorders may also have co-occurring physical deficits related to their primary impairment (e.g., Down syndrome, cerebral palsy) that limit them physically (Jain et al., 2022; Vitrikas et al., 2020). These physical limitations may include balance, strength, and coordination (Rimmer & Marques, 2012).

Children with DS are at increased risk for sedentary behaviors, with 58% of children with DS not meeting the 60 minute daily physical activity recommendation (Shields et al., 2009). Barriers to participation in physical activity have also been explored in adults with DS, finding lack of support (i.e., transportation, support personnel, help with cost, lack of community programs, lack of acceptance), lack of interest (i.e., not enjoying physical activity, concentration difficulties), and physical ability (Mahy et al., 2010). Co-existing physical impairments in children with DS may impact inclusion in activities that incorporate movement and build executive functioning (Arumugam et al., 2016). Individuals with DS face challenges with gross motor skills, specifically balance and postural control caused by hypotonia (Capio et al., 2018; Guzmán-Muñoz et al., 2017; Lauteslager et al., 1998). Static and dynamic movements can be difficult for this population, and exercise interventions are often found to be helpful (Aly & Abonour, 2016; Mehralitabar et al., 2016). When children with DS are included in structured physical activity programs, positive effects on physical ability and executive functioning skills are seen (Becker & Dusing, 2010; Moraru et al., 2015).

Children who are DHH are 33% less likely to meet physical activity guidelines than their typically hearing peers and are 31% less likely to participate in sports (DeLuca & Rupp, 2022). However, a systematic review by Xu and colleagues (2020) found that children who are DHH are more physically active than children with other types of disabilities (i.e., vision deficits, physical disabilities, intellectual disabilities, autism spectrum disorder, chronic medical conditions, behavioral disorders). Barriers to participation for children who are DHH include wearing and use of amplification devices during the physical activity and the auditory environment of the activity (Stewart & Ellis, 2005). In some cases, children with sensorineural hearing loss have been found to have postural instabilities and balance and gait disorders (Mazaheryazdi et al., 2017; Sokolov et al., 2019;).

Relationships between Domains

Dynamic systems theories offer a mechanistic explanation for how a child's multiple systems, including the motor system, work together in development. A child develops as a whole; but within this whole system, multiple subsystems exist (i.e., motor, executive functioning, language). These subsystems are independent, yet they interact to influence the end product of development (van Geert, 2000). This means that there is not one singular path towards language development; instead, language development happens dynamically as new connections between domains are created and strengthened internally given external opportunities and challenges in the environment (Smith & Thelen, 2003). Consider the dynamic systems theories when considering word learning; multiple systems including perception, action, attention, and memory interact to help a child learn a new word (Samuelson et al., 2017). Comparably, the dynamic systems theory of motor movements would argue that environmental constraints, task demands, and individual characteristics including age, language skill, and cognitive level impact movement; therefore, a single motor movement, such as kicking your leg, is not fully explained by a linear view of neuronal firing and muscle contractions alone, but is due to a complex series of coordinated but related actions affected by several additional factors (Thelen, 2005).

Further, dynamic systems theory can be directly applied to the link between structured physical activity, cognition, and language—opportunities for motor movement provide external opportunities that directly and indirectly develop language and cognition (Iverson, 2010). Even in infancy, tasks like crawling, which is a motor activity that engages the independent physical domain of development, interacts internally with other evolving systems and provides external opportunities for language stimulation (e.g., when a child can crawl, the adults around the child begin to use new language structures and the child can explore new environmental stimuli; Iverson, 2010; Smith & Thelen, 2003). Studies regarding semantic richness offer support for the dynamic systems theory of language development (Buchanan & Westbury, 2001; Lund et al., 2015; Pexman et al., 2003; Siakaluk et al., 2008). Semantic richness can be defined as a person's semantic and world knowledge related to a particular word (Lund et al., 2015). The imagery or memories of a physical experience can positively impact a word's semantic richness (Siakaluk et al., 2008). Words that are semantically rich are recalled more quickly than words that lack semantic richness; if a word has more salient factors to it, a child can recall and use the word more quickly than words that lack an abundance of salient features (Buchanan & Westbury, 2001; Pexman et al., 2003; Siakaluk et al., 2008). For children with language difficulties, semantic richness can lead to greater learning outcomes by adding saliency to words making them more memorable or more easily organized into a child's existing world and semantic knowledge (Lund et al., 2015). Physical semantic richness (i.e., physical experiences with words; such as actually throwing a ball when learning the word "throw") is particularly useful for children with low nonverbal cognitive skills (Lund et al., 2015; Mattingly et al., submitted).

The dynamic systems theory provides a clear picture of how the domains of development are independent yet interrelated; however, to date, physical activity has never been studied as a potential moderator of the effect of executive functioning on language skills, particularly in children with disabilities. There have been studies evaluating the relationships between physical activity and cognition, executive functioning and language, and even physical activity and language (e.g., Carson et al., 2016; Kapa & Erikson, 2019; Nejati, 2021); however, the relationship between all three has not been studied. Additionally, the relationship between physical activity and the domains of language (e.g., Mellor & Morini, 2023; Pruitt & Morini, 2021) and between physical activity and executive functioning (e.g., Rudd et al., 2021; Shen et al., 2020) has primarily been studied in children with intact systems and children with disabilities are often specifically excluded. Comparisons between disability profiles have never been made across all three systems when considering how overall development and development of independent systems are interrelated. Understanding of these inter-domain relationships within varying disability profiles is needed to begin utilizing these relationships to make interventions more efficient. Domain-specific interventions account for less than 50% of variance in growth for children with disabilities (Yoder & Compton, 2004); thus, understanding how to utilize multi-domain interactions could lead to more effective interventions.

Domain interactions may differ based on underlying disability diagnoses. A dynamic systems model would predict that for children with disabilities, gaps in development of one subsystem would affect the development of another, meaning the executive functioning, language, and motor domains could be co-affected systems depending on the type and severity of the disability. Executive functioning skills can be considered functional individual constraints that further shape a child's development, and deficits in the executive functioning domain could have broad effects on how a child develops. Language outcomes for children with disabilities likely are more varied than for typically developing children. Executive functioning deficits vary in severity and type in children with disabilities. Children who have a sensory-based disability such as hearing loss may have executive functioning deficits in verbal working memory, fluency-speed, and inhibition-concentration due to delays in language and auditory access as well as listening fatigue (Kronenberger et al., 2020; Nittrouer et al., 2017). Children with global delay such as DS have often more severe deficits in all areas of executive functioning which then impact their ability to learn within their environment (Loveall et al., 2017).

Although we know that children develop as dynamic systems, we do not know how participation in structured physical activities relates to language and executive functioning development in children with disabilities because no single domain develops in a vacuum (i.e., there are internal and external relationships at play). Further, if children with unique disability profiles show differing relationships between domains, this finding will, in the future, have implications for differentiated interventions according to disability type and adaptations necessary for inclusion in structured physical activity opportunities.

Aims of the Study

The purpose of this study was to evaluate the role of physical activity in language and executive functioning development in children with secondary language disorders and to compare the differences in the domain relationships according to disability type. The following questions were answered:

(1) Do between-group differences exist between children with diagnoses associated with global delays (i.e., Down syndrome), children who are deaf and hard of hearing without intellectual disability, and children who do not have a disability diagnoses in the following domains?

(a) participation in structured physical activity

(b) executive functioning

(c) language skills

Hypothesis:

(a) For physical activity, we anticipate that children who are typically developing will have higher reports of participation in structured physical activity than children who are DHH, who are 31% less likely to participate in sports than their typically developing peers (DeLuca & Rupp, 2022). Children with DS are anticipated to have the lowest level of structured physical activity participation due to physical limitations (i.e., hypotonia, physical disabilities, heart conditions) in addition to societal barriers (e.g., lack of disability-friendly sports teams).

(b) For executive functioning, we expect that children who are typically developing will have a range of executive functioning skills that falls within an expected average level of functioning. Children who DHH are expected to have lower executive functioning scores than their typically developing peers, due to the potential decreased environmental input to the auditory pathway that is needed to build executive functioning (Kronenberger, et al., 2020). Children with DS are expected to have the lowest executive functioning scores due to the co-occurring intellectual disability (Daunhauer, et al., 2014).

(c) For language skills, we anticipate that there will be a range of language skills within each group; however, this range will be wider for children who are DHH than children who are typically developing and lowest for children with DS.

(2) Does group membership account for significant variance in the relation between language and executive functioning, indicating that the relation varies by diagnosis?

Hypothesis: Children with varying disability profiles present with different executive functioning and language needs; hence, the relationship between domains will vary between groups (Kapa et al., 2017). We suspect that group membership will account for significant variance in the relation, and that when follow-up correlations are measured by group, the relation for children who are typically developing will be weaker than for the children with disabilities. Children with DS may lack foundational executive functioning skills, which may weaken the overall relationship, meaning children who are DHH may have the strongest relation between language and executive functioning.

(3) Does physical activity moderate the relation between language outcomes and executive functioning even when group membership is accounted for?

Hypothesis: Physical activity has been tied to improved executive functioning (Rudd et al., 2021), and improved executive functioning has clear correlations with language outcomes (Huang et al., 2020). We hypothesize that participation in physical activities moderates the relationship between language and executive functioning for all participants. Children who participate more in physical activity will have stronger executive functioning and language. However, on follow-up, we anticipate that because there may be external barriers to participation for children in the group with DS, that physical activity experience may be less varied and therefore not moderate the language and executive functioning relationship as strongly as for children in the typically developing group or the DHH group.

Methods

Design

A, quantitative design was used to measure the language (i.e., scores on the Clinical Evaluation of Language Fundamentals), executive functioning (i.e., scores on the NIH Toolbox and the Behavior Rating Inventory of Executive Function), and participation in structured physical activity of children who are typically developing and those with disabilities (i.e., DHH or DS) between the ages of 7 and 18 years. All procedures in this study were approved by the Texas Christian University Institutional Review Board.

Participants

Participants in this study were recruited in various ways. The majority of the participants who were DHH in addition to half of the participants who were typically developing are current participants in a larger longitudinal study investigating language and literacy acquisition in children who are DHH (Emergent Language and Literacy Acquisition in Children with Hearing Loss (ELLA); R01 DC017173 funding from the NIH/NIDCD). Children with typical hearing, children with hearing aids, and children with cochlear implants are recruited to participate in the ELLA study. To participate in the ELLA study, children who have hearing loss did not have additional diagnosed disabilities known to affect cognitive and/or language development (e.g., Autism, cerebral palsy, DS). Children in the current study were developing spoken language as a communication modality, but some also used signed language (e.g., American Sign Language) to communicate.

The remaining children were recruited via community connections, including partnerships with adaptive dance and sports classes and local clinics. Participants were recruited nationally through connections, with the majority residing in Texas. For the purposes of this study and to ensure some limitations in variance of disability profile, DS was used to represent global delay. To be included in the participants with DS, children had a parent-confirmed diagnosis of DS, including children with dual diagnoses such as autism and hearing loss. Mode of communication freely varied (i.e., oral language, use of augmentative and alternative communication). To be included in the group of participants who are typically developing, children scored above 70 on the standardized language measures and the measure of nonverbal intelligence (i.e., the *Test of Nonverbal Intelligence-Fourth Edition)*, and they did not have a diagnosis of a hearing loss or biomedical disability. Attention Deficit (Hyperactivity) Disorder was suspected in some participants but not diagnosed. Extant research on executive functioning skills in bilingual children indicates it may be different than for monolingual children (Foy & Mann, 2013; Park et al., 2018); hence, children who were multilingual (i.e., exposed to a language other than English more than 10% of the time in the home) were excluded.

Participants included 75 children who met inclusion criterion from the three groups: 25 children who were typically developing, 25 children who were DHH, and 25 children with DS. Children ranged in age from 7 years 1 month to 18 years 9 months, with children in the DS group having a higher mean age than the other two groups. In our final sample of participants with DS, 1 participant also had an autism diagnosis, 2 participants had an ADHD diagnosis, and 3 participants had mild conductive hearing loss (1 who wore hearing aids), and 1 participant had a moderate conductive hearing loss diagnosis (wore bilateral hearing aids). Only 1 participant with DS utilized a device to supplement his communication; this child relied on spoken language. Table 1 lists the demographic characteristics of the child participants by diagnosis. Maternal educational level is reported due to its known effect on language, literacy, health, and economic outcomes (Dollaghan et al., 1999; Jackson et al., 2017; Nepal, 2018).

Table 1. Demographic information by group

	TD	DHH	DS
Age	114.6 months (30.25)	108.56 months (22.03)	137.96 (41.54)
Gender	Male: 11 Female: 14	Male: 10 Female: 15	Male: 14 Female:11
Race and Ethnicity	White: 24 No Response: 1 Hispanic/Latinx: 4	White: 22 Black: 1 Asian: 1 Multiple: 1 Hispanic/Latinx: 2	White: 21 Black: 2 Multiple: 1 No Response:1 Hispanic/Latinx: 4
Maternal Education Level	Some College: 1 Bachelors: 10 Graduate: 14	Some High School: 1 High School: 1 Some College: 3 Bachelors: 11 Graduate: 9	Some College: 3 Bachelors: 14 Graduate: 8

Note. TD = children who were typically developing, DHH = children who are Deaf and Hard of Hearing, DS = children with Down syndrome

Procedure

Participants were assessed one-on-one with an examiner in a quiet space (i.e., university laboratories, conference rooms, or their home). Examiners were ASHA-certified speech-language pathologists with experience in test administration. For the DHH group, participants' listening devices (i.e., hearing aid or cochlear implant) were in working condition at the time of testing. Children were allowed breaks as needed to encourage continued participation, and testing could be spread over multiple days. Test administration was video- and audio- recorded to calculate scoring reliability and procedural fidelity. A parent of each participant completed questionnaires, including the physical activity and executive functioning measures. Participants completed a battery of language and executive functioning testing during testing sessions that lasted approximately 2 hours.

Measures

Variables

Time spent participating in structured physical activities, which is defined as the dosage of participation across their lifetime (years of participation x months per year participated x monthly frequency x minutes per session) divided by the child's age in years was used as the study's motor domain variable. Additional variables included disability type (e.g., typically developing, DHH, Down syndrome), an omnibus language variable inclusive of scores on the Clinical Evaluation of Language Fundamentals-Fifth Edition, and omnibus executive functioning variables (e.g., the NIH Toolbox subtests and the Behavior Rating Inventory of Executive Function-Second Edition).

Instruments

Measures of Executive Functioning.

NIH Toolbox. The NIH Toolbox Cognition Battery (Gershon et al., 2010) was administered via an app on a tablet. It is recommended for ages 7-18, and it includes the following measures: (1) The Flanker Inhibitory Control & Attention Test assesses attention and executive functioning by having a child choose an arrow to match the way the fish in the middle of the screen is facing. (2) The Picture Sequence Memory Test assesses episodic memory by asking participants to reproduce a sequence of pictures that are related to a theme (e.g., going camping) that are presented visually and via audio. (3) The List Sorting Working Memory Test assesses working memory by asking the child to recall a growing list of words that are presented visually and via audio and sequence them according to size and/or category. (4) The Dimensional Change Card Sort Test assesses executive functioning and attention by having the participant match a picture to a target picture based on an auditory cue asking of "color" or "shape." (5) The Pattern Comparison Processing Speed Test assesses processing speed by asking the participant to determine whether two pictures are the same or different. There have been several studies assessing reliability and validity of the NIH Toolbox. Reliability and convergent validity ranged from moderate to strong in children with intellectual disabilities (Shields et al., 2020) and was reported as excellent across children ages 8-15 (Akshoomof et al., 2013).

BRIEF-2. The Behavior Rating Inventory of Executive Function-Second Edition (BRIEF-2; Gioia et al., 2015) consists of two rating forms, one for the parent and one for the child; the parent form was used for the present study. It is recommended for ages 5-18, and it evaluates the cognitive, behavioral, and emotional regulation domains, providing a composite score for executive functioning skills. It includes the following scales within the above-named domains: Inhibit, Self-Monitor, Shift, Emotional Control, Working Memory, Plan/Organize, Initiate, Task-Monitor, Organization of Materials, and Task Completion. Parents are asked to rate how often certain behaviors have been a problem with rating options being “never,” “sometimes,” or “often.” Reliability and validity have been reported: high internal consistency with coefficients ranging from .71 to .97; test-retest correlations ranging from .67 to .92; internal validity with correlation coefficients ranging from .44 to .77; concurrent validity with moderate to strong relations between the BRIEF-2 and similar measures (Hendrickson & McCrimmon, 2019).

Measures of Language. The *Clinical Evaluation of Language Fundamentals-Fifth Edition* (CELF-5; Wiig et al., 2013) was used as an omnibus language measure. Subtests of the CELF-5 were administered, and the combined core language score was calculated. Administer subtests included: Sentence Comprehension, Word Structure, Formulated Sentences, Recalling Sentences, Word Classes, Semantic Relationships, and Understanding Spoken Paragraphs. These subtests cover both expressive and receptive language and provide a composite measure of these skills. The CELF-5 has good reliability and validity: internal consistency reports ranged between acceptable to excellent (.60 to .99); test-retest stability ranged from poor to excellent (.56 to .93); interrater reliability was excellent (.91 to .99); concurrent validity ranged from adequate to excellent (.64 to .98); interrelationships among all subtests and composites were found to range from good to strong (Coret & McCrimmon, 2015).

Measure of Physical Activity. Reports of participation in structured physical activities were collected via a questionnaire from a parent of the participant. Questions included experience in physical activities, frequency and duration of structured physical activities, and specifics regarding types of structured physical activities. Structured physical activities for this study were defined as sports or other physical activities that were goal-directed and taught by an instructor. This questionnaire was developed by a team of three researchers, including one kinesiologist and two speech-language pathologists. Questionnaire items went through a 2-step review, with team members unanimously agreeing to the content on the second version of the questionnaire. Time spent participating in structured physical activities per year was quantified as the dosage of participation across their lifetime (years of participation x months per year participated x monthly frequency x minutes per session) divided by the participant's age in years. This number was divided by 52 to convert the measure to minutes per week.

Additional Measures. Additional instruments were used for eligibility and/or descriptive purposes. These included a nonverbal intelligence score on the *Test of Non-verbal Intelligence-Fourth Edition* and parent questionnaire regarding the participant background.

Nonverbal intelligence. The *Test of Non-verbal Intelligence* (TONI-4; Brown, et al., 2010) is a standardized test assessing two components of intelligence – abstract reasoning and problem solving – in children. Children were asked to identify what figure is missing within a sequence of abstract figures. The figures have one or more notable attributes, and items become harder as more attributes are added. The first 19 items are for children ages 6 to 9, and the remaining items are designed for children 10 years and older. The TONI-4 has reported good internal consistency (.92 to .97), test-retest reliability (.88 and .93), alternate form reliability (.67 to .89), interscorer agreement (.99), acceptable content validity (coefficients above 50%), construct validity (.55 to .79), and predictive validity (Ritter et al., 2011).

The measures described above were video and audio-recorded as part of the protocol. Reliability was checked on 45% of the sample. Reliability was above 95% across measures, so the first-author scoring was used for all analyses.

Results

The objective of the study was to understand inter-domain relationships in the areas of language, executive functioning, and physical activity in children with disabilities and to compare the differences in the domain relationships according to disability type.

All 75 children completed a battery of testing to measure language (standard score on the CELF-5) and executive functioning (composite score on the NIH Toolbox. Parents of the 75 participants completed the parent report form of the BRIEF-2, creating the Global Executive Composite. One parent of a child who was typically developing did not complete the parent questionnaire which provided report of physical activity; all other parents completed the questionnaire. Thirteen participants with DS and two who were DHH were unable to complete one or more subtests of the NIH Toolbox. For this reason, the parent report on the BRIEF-2 completed by all 75 participants was used as the main EF measure, and the Toolbox was used as a secondary measure.

Descriptive Information

The participant sample was equally distributed among the three groups, with 25 participants in each diagnostic group. All participants ranged from 7 years and 1 month of age to 18 years and 9 months, with participants with DS averaging higher ages. This greater variation in age allowed for increased variability in performance on all outcome measures. Gender, race, ethnicity, and maternal education were similar among groups. Due to the DS group having 4 participants with co-occurring hearing loss, all analyses were run with and without these 4 participants included. The results did not significantly differ. The analyses shown below include all 25 DS participants. Demographic information is presented in Table 1.

All three groups varied in performance on all outcome measures. Children with typical development had the highest amount of yearly participation in structured physical activity (64.58 minutes per week). Children who were DHH had the second highest (43.87 minutes per week), and children with DS had the lowest (28.6 minutes per week). Children who were typically developing had the best scores on parent-reports of executive functioning (47.2±8.5; lower scores mean less difficulty) as well as on performance-based measures (108.12±13). Children who were DHH had slightly more reported problems with executive functioning (51.64±9.9) and slightly lower scores on the NIH-Toolbox (100.7±12) than their typically developing peers. Children with DS had higher average scores on the BRIEF-2 (66.44±8.7, indicating greater EF difficulty) and lower average scores on the Toolbox (55.73±11) than children who were TD and those who were DHH but similar standard deviations. In regard to language scores on the CELF-5, children who were TD had the highest scores (104.84±12) followed by children who were DHH (96.32±20). Children with DS had very low scores on the CELF-5 with little variability (45.32±5.6), reflecting a floor effect for these children. See Table 2 for means and standard deviations for each domain and see group comparisons in question 1 results section.

Table 2. Means and Standard Deviations for each domain**.**

Development Groups	n	Physical Activity (in minutes per week)	BRIEF-2 Global Executive Composite	NIH Toolbox Composite Score	CELF-5 Core Language Score
Typically Developing	25[a]	64.58 (69.87)	47 (8.5)	108 (13)	105 (12)
Deaf and Hard of Hearing	25[b]	43.87 (55.49)	52 (9.9)	101 (12)	96 (20)
Down Syndrome	25[c]	28.6 (32.72)	66 (8.7)	56 (11)	45 (5.6)

[a]Number of participants was only 24 for the physical activity measure.
[b]Number of participants was only 22 for the NIH Toolbox measure.
[c]Number of participants was only 11 for the NIH Toolbox measure.

Question 1

The first research question asked if between-group differences in the domains of physical activity, language, and executive functioning exist between children with diagnoses associated with global delays (i.e., Down syndrome), children who are deaf and hard of hearing but do not have additional intellectual disability diagnoses (i.e. DHH group), and children who do not have any disability diagnoses (i.e. typically developing group). A one-way ANOVA was run for each domain to determine if there was a significant difference between groups.

Physical Activity

For physical activity, data was not normally distributed for any of the groups, as assessed by the Shapiro-Wilk test of normality ($p<.001$). Each group had outliers—typically developing had 1, DHH had 1, and DS had 2. Outliers were reviewed for accuracy, and they were determined to be accurate and are not concerning. The assumption of homogeneity of variance also was not met ($p=.034$). Due to the assumptions of normality and homogeneity not being met, a non-parametric Kruskal-Wallis Test was conducted to examine the between-group differences of how much time participants spend participating in a structured physical activity in a year. No significant differences $H\ (2,74) = 4.54$, $p = .104$ were found among the three participant groups as an overall main effect. Overall, there was a small effect size, $\eta^2=.04$ (Tomczak & Tomczak, 2014). Because this is the first study of its kind, Cohen's d was evaluated for each of the between group comparisons to provide a basis for power calculations for future work. Cohen's d for typically developing versus DHH was -.33 (small effect); typically developing versus DS was -.66 (medium effect); DHH versus DS was -.34 (small effect). See Figure 1 for the boxplot showing the distribution of the amounts of yearly physical activity in minutes per week by diagnostic group.

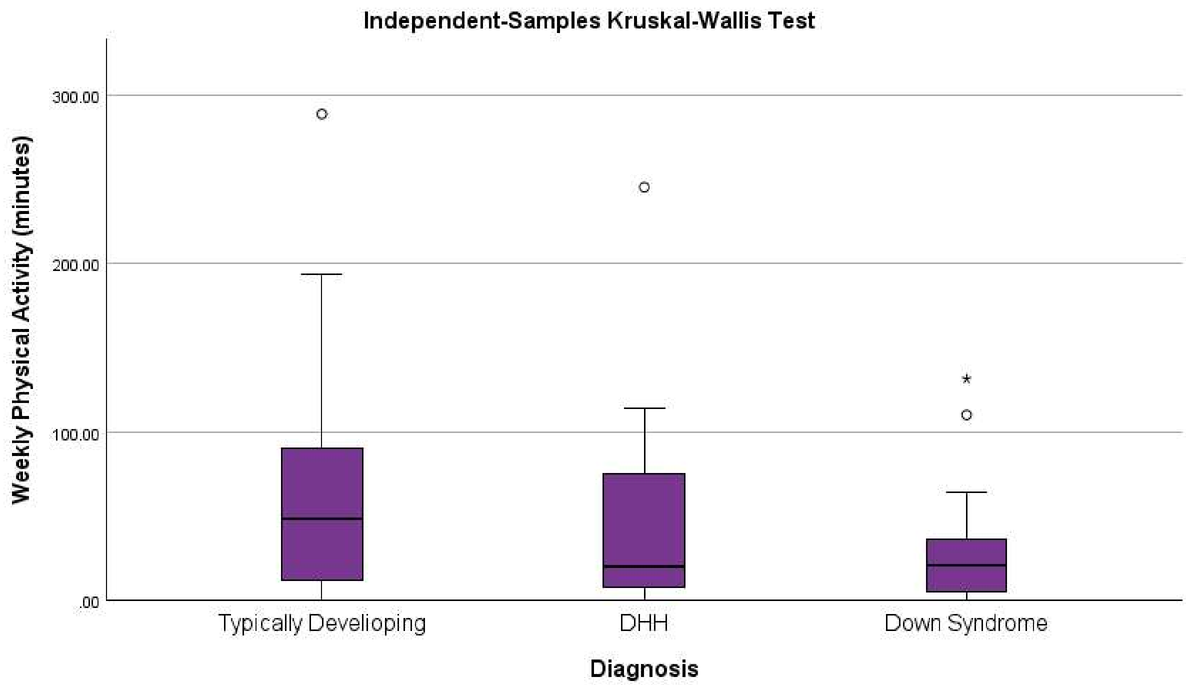

Figure 1. Distribution of amount of physical activity by diagnostic group, where ° denotes an outlier and * denotes an extreme outlier.

Executive Functioning

BRIEF-2. For executive functioning as reported by the Global Executive Composite on the BRIEF-2, all assumptions were met. A one-way ANOVA revealed that the groups are significantly different in terms of executive functioning skills, F (2, 72)= 30.7, p <.001, with a large effect size (η^2=.46). Post-hoc analysis revealed that participants with DS had significantly higher scores than children who are DHH (p <.001; d = -1.58)and children who are TD (p <.001; d = -2.23), meaning children with DS had more reported executive functioning problems. The mean difference between DHH and TD was non-significant (p <.265; d = -.48). See Figure 2 for the boxplot showing the distribution of the Global Executive Composites on the BRIEF-2 by diagnostic group.

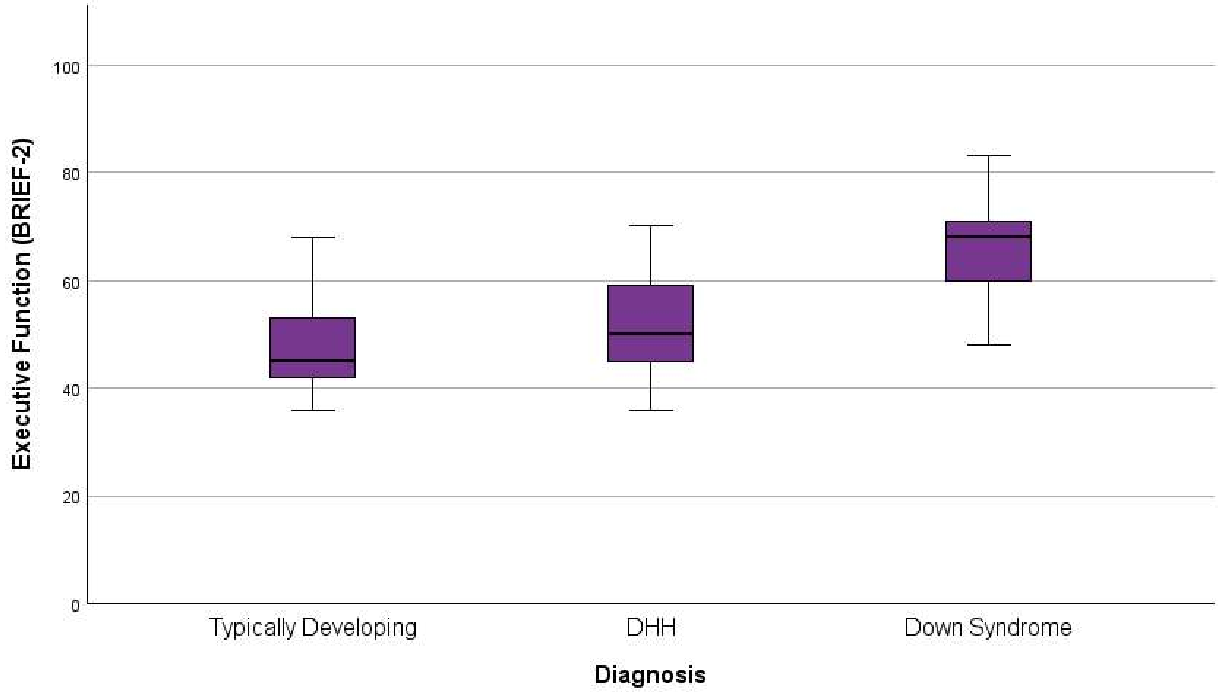

Figure 2. Distribution of Global Executive Composite on the BRIEF-2 by diagnostic group (higher scores mean more executive functioning difficulties)

NIH Toolbox. For executive functioning as reported by the NIH Toolbox Composite Score, a one-way ANOVA had the same findings, F (2, 56) = 72.43, p <.001, with a large effect size (η^2=.72). Post-hoc analysis on this measure also revealed that participants with DS scored significantly lower than children who are DHH (p <.001; d = 3.89) and children who are TD (p <.001; d = 4.29). The mean difference between DHH and TD was non-significant (p <.102; d = .59), with the children who were DHH scoring lower on average.

There were a number of children with disabilities that were unable to complete the NIH-Toolbox (13 children with DS and 2 children who were DHH). Past studies suggest that parent report measures of executive function assess different constructs of executive functioning than performance-based measures (Ten Eycke &Dewey, 2015; Vriezen & Pigott 2010). Our sample showed similar results according to group on both parent-report measures and performance-based measures of executive functioning. To determine the correlation of both measures to each other in this sample, a correlation analysis was conducted for the two executive functioning measures (NIH Toolbox and BRIEF-2). The NIH Toolbox score (higher score means better executive functioning) is significantly negatively related to the BRIEF-2 score (higher score means worse executive functioning), r =-.468, p <.001. Because there were more completed BRIEF-2 reports than Toolbox tests, for the remainder of the analyses, the BRIEF-2 is used as the measure of EF.

Language

For language as reported by the Core Language Score on the CELF-5, the assumption of normality was met for all groups except DS. The DHH group had 2 outliers, but neither of them were influential. The assumption of homogeneity of variance also was not met for any of the groups. For this reason, non-parametric testing Kruskal-Wallis Test was conducted, and significant differences were found (H (2,75) = 49.56, p <.001). The effect size was large, η^2 =.66. Pairwise comparisons revealed that the children with DS scored significantly lower than children who were DHH (p <.001; d = 3.52) and children who were typically developing (p <.001; d = 6.27); however, there was not a significant difference between children who were DHH and children who were typically developing (p =.211; d = .52). See Figure 3 for the boxplot showing the distribution of the Core Language Score on the CELF-5 by diagnostic group.

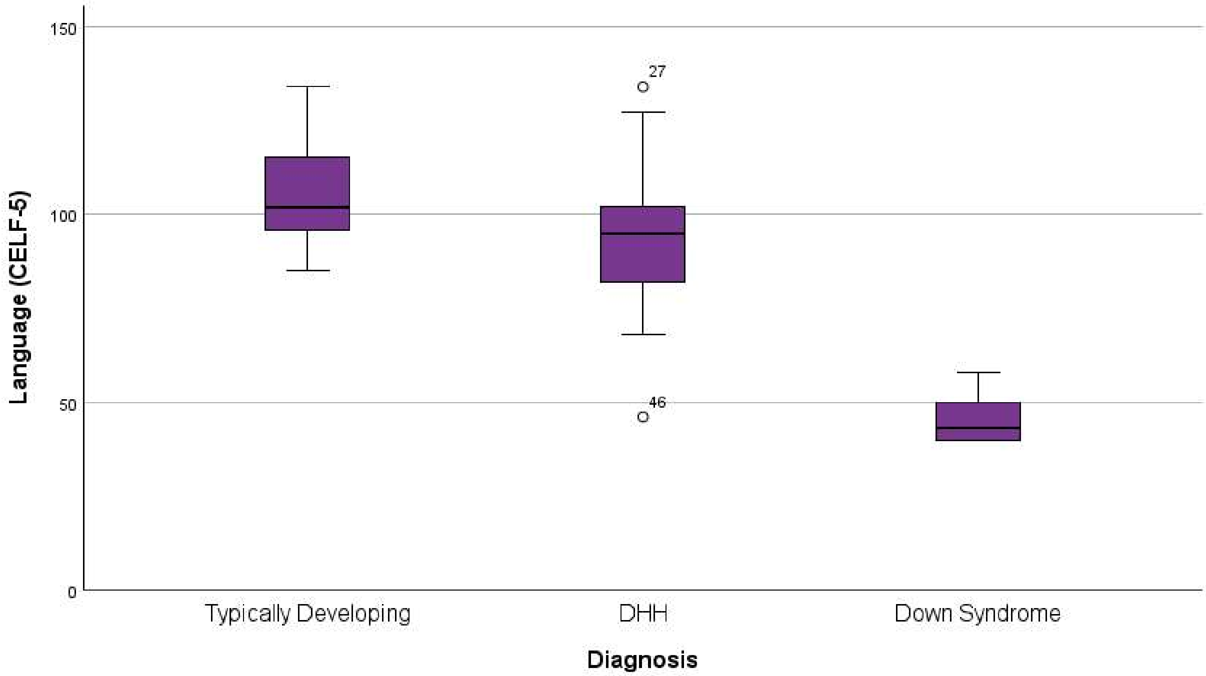

Figure 3. Distribution of Core Language Score on the CELF-5 by diagnostic group, where ° denotes an outlier.

Individual correlations were run between each domain, using Kendal's tau due to previously discussed assumption violations. Overall, executive functioning was significantly correlated with physical activity (p=.038) and language (p<.001). For children who were TD, physical activity was significantly correlated with language (p=.05). For children who were DHH, executive functioning and language were significantly correlated (p=.043). No significant correlations were found for DS. Results can be seen in Table 3.

Table 3. Correlations between domains by group

Development Groups	Physical Activity	Executive Function (BRIEF-2)	Language (CELF-5)
All			
Physical Activity	1	-.167*	-.026
Executive Function	-.167*	1	-.508**
Language	-.026	-.508**	1
Typically Developing			
Physical Activity	1	-.007	-.29*
Executive Function	-.007	1	-.131
Language	-.29*	-.131	1
Deaf and Hard of Hearing			
Physical Activity	1	-.112	-.228
Executive Function	-.112	1	-.296*
Language	-.228	-.296	1
Down Syndrome			
Physical Activity	1	-.264	.092
Executive Function	-.264	1	-.288
Language	.092	-.288	1

*p<.05; **p<.001

Question 2

The second question asked if group membership accounts for significant variance in the relation between language and executive functioning. As is common with data from populations with intellectual and/or developmental disabilities (Vagenas & Totsika, 2018), the residuals of the data were not independent but displayed positive autocorrelations. For this reason, linear mixed models were used. Model 1 used the Core Language Score on the CELF-5 as the outcome variable and the Global Executive Functioning (EF) score on the BRIEF-2 as the fixed effect without a random effect. Model 2 used the Core Language Score on the CELF-5 as the outcome variable and the EF score on the BRIEF-2 and diagnostic group as fixed effects. Model 3 used the Core Language Score on the CELF-5 as the outcome variable and the Global Executive

Functioning EF score on the BRIEF-2 as fixed effects and diagnostic group as a random effect. EF was chosen as a fixed effect due to the question's interest in EF's specific effect on language. Diagnostic group was allowed to be a fixed effect or random effect to assess the role of group membership. Due to the DS group having 4 participants with co-occurring hearing loss, all analyses were run with and without these 4 participants included. The results did not significantly differ. The analyses shown below include all 25 DS participants. The Akaike information criterion (AIC) was used to select the statistical model with the best fit (i.e., the lowest AIC value). See Table 4 for all models.

Table 4. Linear Mixed Models for Language Scores

Model Description	**Fixed Effects** - Predictor: Estimate (SE), t-value, p-value, [CI]	**Random Effects** Variance Component: [Value], SD: [Value]	**AIC**	**Notes**
Model 0: Null Model Language ~ 1	Intercept Only	None	724.70	Serves as a baseline for comparison, only including the intercept to assess the average level of language scores without any predictors.
Model 1: EF as Fixed Effect Language ~ EF	Executive Function	None	674.10	Examines the direct effect of executive function on language scores, with no account for group membership.
Model 2: EF and Group as Fixed Language ~ EF + Group	Executive Function Group (as categorical with 2 dummy variables for 3 groups)	None	630.32	Adds group membership as a fixed effect to assess its individual contribution along with executive function.
Model 3: EF as Fixed, Group as Random Language ~ EF + (1|Group)	Executive Function	Group	618.67	Assesses the effect of executive function on language scores while accounting for the variability in language scores due to differences among groups, treated as a random effect.

The model with the best fit was model 3, using EF as a fixed effect and group membership as a random effect. The model revealed a significant main effect for EF score ($\hat{\beta}$=-.523, p = .003). Model 3 shows that BRIEF-2 scores significantly predicted CELF-5 scores when the group is treated as a random effect. See table 5 for model statistics.

Table 5. Model 3 Statistics

CELF-5 Score	β	*SE*	95% CI	*t*	*p*	R^2	f^{22}
Model 3						.753	*3.05*
Constant	110.98	15.71	[73.69, 148.27]	7.07	<.001		
EF	-.52	.17	[-.86, -.19]	-3.12	.003		

Note: β= unstandardized regression coefficient; SE=standard error; CI=confidence interval; t=test statistic; p=p-value; R^2=coefficient of determination; f^2=Cohen's f effect size; EF=Global Executive Functioning Composite Score on the BRIEF-2

Third Question

The third question asked if physical activity moderates the relation between language outcomes and executive functioning even when group membership is accounted for. Again, linear mixed models were used. Model 0 used the Core Language Score on the CELF-5 as the outcome variable and the EF score on the BRIEF-2 as fixed effects and diagnostic group as a random effect. Model 1 used the Core Language Score on the CELF-5 as the outcome variable and the EF score on the BRIEF-2 and participation structured physical activity (PA) as fixed effects and diagnostic group as a random effect. Model 3 used the Core Language Score on the CELF-5 as the outcome variable and the EF score on the BRIEF-2, participation in structured PA, and the interaction of EF x PA as fixed effects and diagnostic group as a random effect. Due to the DS group having 4 participants with co-occurring hearing loss, all analyses were run with and without these 4 participants included. The results did not significantly differ. The analyses shown below include all 25 DS participants.

Model 2 with the interaction effect was the best fit. Additionally, the value of -2 Restricted Log Likelihood decreased from model 1 to model 2 (difference of 4.44), meeting the critical value for chi-square (>3.84) meaning the change was significant. Table 6 displays each model.

Table 6. Linear Mixed Model for Interaction Effects

Model Description	Fixed Effects - Predictor: Estimate (SE), t-value, p-value, [CI]	Random Effects Variance Component: [Value], SD: [Value]	AIC	Notes
Model 0: EF as Fixed, Group as Random Language ~ 1	Executive Function	Group	618.67	Serves as a baseline for comparison; the best fit model from question 2.
Model 1: EF and PA as Fixed Effects, Group as Random Language ~ EF + PA + (1|Group)	Executive Function Physical Activity	Group	607.41	Examines the direct effects of executive function and physical activity on language scores, accounting for the variability in language scores due to differences among groups
Model 2: EF, PA, and EF x PA interaction as Fixed Group as Random Language ~ EF + PA + EFxPA +(1|Group)	Executive Function Physical Activity Interaction of EF x PA	Group	604.97	Adds the interaction of executive functioning and physical activity as a fixed effect to assess its moderation effect along with the individual contributions of executive function and physical activity.

Model 1, which included fixed effects of EF and PA, accounted for a significant amount of variance in a child's language score, $R^2 = .775$. Model 2 revealed a significant interaction effect of EF x PA ($\hat{\beta}$=.006, *p* =.036), accounting for a significant proportion of the variance in language score than just EF and structured PA by themselves, $R^2 = .785$. See table 7 for model statistics. Thus, physical activity did significantly moderate the relation between executive functioning and language skills even when group membership is accounted for. The moderation effect was relatively low but significant and present such that at lower values of executive functioning (i.e., fewer problems with EF), the impact of participation in physical activity is lower.

Table 7. Model 2 Statistics

CELF-5 Score	β	*SE*	95% CI	*t*	*p*	R^2	f^{22}
Model 2						.785	3.65
Constant	129.21	16.42	[91.5, 166.93]	7.87	<.001		
EF	-.81	.19	[-1.19, -.44]	-4.32	<.001		
PA	-.36	.14	[-.63, -.08]	-2.6	.011		
EF x PA	.006	.003	[.00, .012]	2.14	.036		

Note: β= unstandardized regression coefficient; SE=standard error; CI=confidence interval; t=test statistic; p=p-value; R^2=coefficient of determination; f^2=Cohen's f effect size; EF=Global Executive Functioning Composite Score on the BRIEF-2; PA= participation in structured physical activity

Discussion

The purpose of this study was to evaluate the role of physical activity in language and executive functioning development in children with diagnoses associated with secondary language disorders and to compare the differences in the domain relationships according to disability type. Group-based differences were found in the executive functioning and language domains, specifically for the children with DS who have significantly more reported difficulties with executive functioning and lower language scores than children who are typically developing and children who are DHH. Additionally, executive functioning was found to be a significant predictor of language scores, especially when accounting for the variability in language scores to differences among groups. Further, participation in structured physical activity moderated the effect of executive functioning on language skills.

Executive Functioning and Language

The relationship between executive functioning and language found in this study was consistent with past studies of executive functioning and language skills (Danhauer, 2014; Kapa & Erikson, 2019; Marini et al., 2020). There was an overall negative correlation between executive functioning and language for the participants in the present study (meaning that language score rises as fewer executive functioning weaknesses are observed). Additionally, through linear mixed models, we found that executive functioning skills are a significant predictor of language skills especially when accounting for variability in language scores due to differences among groups. These findings support the suggestion made by Weiland and colleagues (2014) that executive functioning ability can aid language development. Executive functioning indeed appears to have a role with learning–controlling both actions and thoughts which are required for learning to occur (Anthony & Ogg, 2020; Garner, 2009). This role translates to language learning, with skills such as memory, attention, and inhibitory control impacting one's ability to learn language. However, the current study did not evaluate the suggested bidirectionality of the relationship, with language skills predicting executive functioning outcomes (Tomas & Vissers, 2019). Future studies evaluating the reciprocal nature of language and executive function are warranted.

The present study found differences between groups in terms of executive functioning skills. As expected, children with DS significantly differ from children who are typically developing and those who are DHH. Similar to findings from numerous studies evaluating executive functioning and language in children with DS, our sample had difficulty on all types of executive functioning skills as well as with language. Unsurprisingly, these deficits really came to light when asking the participants to complete executive functioning tasks via the NIH Toolbox. Only 11 of the 25 participants with DS were even able to complete all 5 subtests of the Toolbox, which may reflect difficulties with foundational executive functioning skills needed to perform these tasks. It is important to note that these 11 children (in addition to the 2 children with DHH who were unable to complete the measure) put appropriate effort in their attempt of the measure and task failure was not due to behavior or noncompliance. It is especially notable that the two subtests assessing memory skills were the hardest for children with DS. In the study by Mattingly and colleagues (submitted), working memory was identified as the key executive functioning skill that correlated with word learning via traditional methods. It appears that performing tasks that require increased memory skills, which is key to traditional learning methods, may be very difficult for children with DS (Daunhauer et al., 2014; Daunhauer et al., 2017). Parent reports of executive functioning skills via the BRIEF-2 also supported the idea that deficits in executive functioning exist for children with DS throughout their development (Liogier d'Ardhuy et al., 2015; Loveall et al., 2017).

Our study found no significant differences between children who are DHH and children who are typically developing in executive functioning skills or language scores. As was expected, children who are DHH scored more poorly than their typically developing peers but within the broad range of normal on both executive functioning measures and the language measure, reflecting past research in the area (Kronenberger et al., 2020; Kronenberger et al., 2018; Kronenberger et al., 2013). Additionally, the present study found significant correlations between language and executive functioning for children who were DHH—the only group this was true for in a group-specific correlation analysis. In comparison to the children with DS, all but 2 children who were DHH were able to complete the NIH Toolbox. For these 2 children, their oral language abilities made it difficult for them to complete the List Sorting Working Memory Test, which is supported by studies that have found that difficulties with speech recognition, vocabulary, and nonword repetition (associated with working memory) is common for children who are DHH (Lund, 2016; Nittrouer et al., 2018; Pisoni et al., 2011).

Physical Activity and Executive Functioning

Although the present study did not find statistically significant relationships between group membership and structured physical activity levels, the difference between groups would appear to be clinically significant. In this sample, typically developing children participate in over 60 minutes of structured physical activity each week, whereas children who are DHH participate in 45 minutes weekly, and children with DS participate in only 30 minutes weekly.

Research shows that children who are more active exhibit positive neurological differences, including better behaviorally-measured attention and memory skills than children who are less active (Cadenas-Sanchez et al., 2023; Shao et al., 2022; Sibley & Etnier, 2003). Physical Activity Guidelines suggest that children above the age of 6 should be getting an hour daily of aerobic physical activity (US Department of Health and Human Services, 2018). Recent studies show that most children do not meet this guideline (Michael et al., 2023; Pate et al., 2015). Children with disabilities are often significantly less active than their peers, participating in physical activities at even lower levels (Rimmer & Rowland, 2008; Sit et al., 2007). The current study had similar findings, with most children having low levels of participation in structured physical activity. Additionally, data from the current study matched the trends suggested by DeLuca & Rupp (2022) and Xu and colleagues (2020), with DHH participating in less structured physical activities than typically developing but more than children with other disabilities. Children with DS had the lowest reports of physical activity participation, also matching previous reports of at least 58% of this group of children not meeting the physical activity guideline daily recommendation (Shields et al., 2009). However, even if all participants received the 30 minutes a day of physical education that most state education agencies require, this still leaves them well under the guidelines. Past research has found physical activity to have positive influences on executive functioning, with doses of aerobic physical activities as small as 20 minutes making a mark (Davis et al, 2011; Khodaverdi et al., 2021). When children with DS are included in structured physical activity programs, positive effects on physical ability and executive functioning skills are seen (Becker & Dusing, 2010; Moraru et al., 2015). Hence, increasing physical activity could be impactful for all children but especially for those who already have deficits in executive functioning. The present study found a significant correlation between the amount of physical activity and executive functioning for the entire sample, supporting findings from a number of studies which utilized movement to improve executive functioning skills (Begel et al., 2021; Cherriere et al., 2020; Lakes & Hoyt, 2004; Lakes et al., 2019; Majorek et al., 2004; Manjunath & Telles, 2001; Oppici et al., 2020; Rudd et al., 2021; Shen et al., 2020; Zach et al., 2015).

Physical Activity and Language

The findings from the current study support the existing research which posits that more physical activity is associated with better language outcomes (Carson et al., 2016; Mellor & Morini, 2023; Pruitt & Morini, 2021). In group-specific correlation analyses, we found that the amount of physical activity was positively correlated with language scores for children who are typically developing but not for our children with disabilities. This suggests that the relationship between structured physical activity and language may be different for children with disabilities. As seen in the example of unassisted sitting in infants, delays in attaining developmental motor milestones may mean fewer opportunities to explore the items and people around them which leads to language development (Iverson, 2021). Although the difference in amount of structured physical activity is not significantly different between groups, there may be a threshold to where the interaction between motor and language domains starts to have an effect, and the our lowest-performing children may not be reaching that threshold. Additionally, there may be a variable that the current study did not consider which may be interacting with physical activity to impact language. In a past study with children with DS, children with higher IQ scores showed benefit from co-treatment from a speech-language pathologist and adaptive PE teacher resulting in expressive word learning as compared to children with DS with lower IQ scores who struggled learning words regardless of co-treatment (Lund et al., 2019). In comparison, children who are DHH who have low language skills and less listening experience benefit from movement integrated instruction than children with DHH who have higher language skills and more listening experience (Lund et al., 2015). Motor delays and motor impairments may be a potential reason for decreased structured physical activity participation in some children, and this decreased time spent in structured physical activity may indeed have cascading effects on language skills (West & Iverson, 2017). Another possible barrier to participation in structured physical activities, especially for children with more severe disabilities, is lack of community support, which includes presence of accessible equipment and programs (Mahy et al., 2010). Lack of community-based programs may result in fewer opportunities for children with disabilities to interact socially, and social engagement has been shown to be important in developing language skills (Blum-Kulka, 2004; Vitiello & Williford, 2016).

Physical Activity, Executive Function, and Language

Prior to the current study, there has not been research attempting to investigate the relationship between participation in structured physical activity, executive functioning, and language skills. By adding physical activity to the model, the model improved significantly. with a significant interaction effect of executive functioning and structured physical activity on language scores. The moderation effect was relatively low but significant and present such that at lower values of executive functioning (i.e., fewer problems with EF), the impact of participation in physical activity on language scores is lower. This finding may mean that the combined effects of executive functioning skills and increases in structured activity participation could be important in the development of language skills. There is a chance that the category of "structured physical activity" is too broad, and a more focused evaluation of subtypes of structured physical activity may be beneficial. Future studies further evaluating this interaction and possible reciprocal interactions and benefits are warranted in order to use this data to inform interventions.

The results from this study align with the Dynamic Systems Theory for whole-child development. There is not one single pathway to develop language, cognition, or motor skills, but instead they appear to interact and react to not only environmental constraints but the individual's constraints such as the presence/absence and severity of a disability (Smith & Thelen, 2003; van Geert, 2000). The dynamic systems model predicts that for children with disabilities, gaps in development of one subsystem would affect the development of another, meaning both language and motor domains could be co-affected systems depending on the type and severity of the disability. The group differences seen in this study support this prediction, with children with global delay (i.e., DS) having more issues in overall development; however, the interconnections between domains were found for children who were DHH as well as those who were typically developing.

Limitations and Future Directions

This study provides avenues for future study for the understanding and use of dynamic systems theory as it relates to language development and intervention. A limitation of this study was its measurement of the motor domain. Parents were asked to report on participation in structured physical activities, but the study did not account for participation in motor activities such as free play or physical education. It is known that unstructured physical activity and physical education in schools help build executive functioning (Kingston et al., 2020; Subramanian et al., 2015); hence, adding a report of participation in unstructured physical activity and physical education could have provided a much more complete picture. Alternatively, the use of a physical activity monitor could be used to acquire reports of amounts and levels of physical activities. Additionally, a physical measure of motor ability could have also been beneficial. For example, both children who have profound hearing loss and those with

DS have higher risk of balance issues which may interact with their development of executive functioning and language (Capio et al., 2018; Melo et al., 2017). Having a measure of motor skills could have been a beneficial piece of information that tied together the domains.

Future research might consider a qualitative study to identify themes surrounding participation in structured physical activities, including existing barriers to participation for the children with disabilities. There was a clear difference in the amount of structured physical activity between groups, and knowing what barriers exist would allow for some of those barriers to be extinguished. Qualitative inquiry would also provide more information regarding connections to the social-emotional domain of development, which is a domain that is important to whole-child development but was not a focus of this study.

A second, related limitation was that the measures for language and executive functioning were not the best for children with global delays as evidenced by a large portion of the sample of children with DS not completing the performance-based executive functioning measure, and experiencing floor effects on the language measure (i.e., the CELF-5). Although the CELF-5 is a reliable and valid measure (Coret & McCrimmon, 2015), it was not a useful measurement of the range of language skills in children with Down syndrome. A clear floor effect was seen in the Core Language Scores of these children. For example, a child who got a raw score of 10 on the Word Classes subtest clearly has a different level of skill than a child who got a raw score of 2; however, standardized scoring would dictate that both of these children would get a standard score of 1, leading to a very low Core Language Score. Hence, the scoring is not fine-tuned enough to measure important differences within this diagnostic group. This is likely related to the overall purpose of a norm-referenced assessment: ultimately norm-referenced measures are designed to diagnose disability and not to capture nuanced differences between children who fall in the lowest or highest percentiles of performance (McCauley & Swisher, 1984). It is possible that future research should include criterion-referenced measures as well for this particular subgroup. Relative to executive functioning, although the BRIEF-2 parent report form was an excellent measure of observed executive functioning, the NIH Toolbox was difficult for many of the children with DS. Only 11 participants with DS were able to complete the Toolbox, leading to the conclusion that another performance-based measurement of executive functioning could have been more informative. Otherwise, parent-based reports may be the best measure of executive functioning we have for children with DS and other global delays.

Given the findings from this cross-sectional study, a longitudinal study may offer even more details about dynamic systems theory and the development of multiple domains. In the present study, we were able to make correlations regarding executive functioning, language, and physical activity; however, we were unable to measure gains in these areas resulting from differing doses of physical activity. All children are born with differing individual constraints that give them a different baseline in skills. A longitudinal study would allow us to evaluate what dose of physical activity is needed to see the impact on development of other domains. Additionally, a future study looking at multi-domain interventions for children with disabilities is warranted. Because this study's findings suggest that movement moderates the effect of executive functioning skills on language development, investing time in developing and evaluating multi-domain interventions is a logical next step.

Conclusion

Overall, this study provides knowledge that aligns with the dynamic systems theory for whole-child development in children with and without disabilities. Significant group-based differences were found in the executive functioning and language domains, with children with DS having more reported difficulties with executive functioning and lower language scores than children who are typically developing and children who are DHH. Executive functioning scores significantly predicted language, especially when accounting for the variability in language scores due to differences among groups. Further, participation in structured physical activity moderated the effect of executive functioning on language skills. These findings encourage further inquiry into the interrelationships between domains as well as support the use of multi-domain interventions for children with disabilities to potentially strengthen both executive functioning and language.

CHAPTER V: CONCLUSION

Summary and Principal Findings

Current literature in both executive functioning and language shows growing interest in the crossover of these domains; however, there is limited work evaluating how such crossover affects children at risk for secondary language disorders, providing a basis to determine how interventions that target multiple domains could benefit these children. The objective of this three-manuscript dissertation was to evaluate the relationship between multiple domains (i.e., language, executive functioning, and motor) in children with secondary language disorders and examine how it compares among varying etiologies. The long-term goal of this line of research is to explore the relation between multiple domains in children with language disorders to understand how the dynamic systems theory can be used to support better language outcomes. The dissertation included three articles, each evaluating multi-domain crossovers in children with secondary language disorders. The first article evaluated the relationship between the executive functioning skill of attention and language in children who are deaf and hard of hearing (DHH). The second article explored how the motor domain can be utilized to build language skills in children with Down syndrome (DS). The third article investigated the relationships between the domains of language, executive functioning, and structured physical activity in children who are DHH, children with DS, and children with no diagnosis, and evaluated how disability etiology played a role in these cross-domain relationships.

Dynamic systems theory of development provided a theoretical background supporting this line of inquiry. The theory posits that multiple subsystems (e.g., motor, executive functioning, language) exist independently of the others, but they interact to influence development (van Geert, 2000). This dissertation work broadly hypothesized that relationships between domains exist and shape development differently based on individual (e.g., disability type) and environmental (e.g., intervention type) constraints. The findings of the three-article dissertation support the hypothesis by identifying relationships between domains for children at risk for secondary language disorders and finding that multi-domain interventions help strengthen development.

Relationships between Manuscripts

This dissertation is comprised of three articles that each seek to answer a separate but related question regarding a dynamic systems-based approach to the development of children at risk for secondary language disorders. The three articles focused on different elements important to the hypothesis of the dissertation.

In the first article, the domains of executive functioning, in this study represented by attention, and language were explored in the DHH population. Prior research looking at the co-occurrence rates of Attention Deficit and Hyperactivity Disorder (ADHD) and hearing loss were generally inconclusive but found that parents of children who are DHH reported more ADHD-associated behaviors than parents of typically hearing children (Theunissen et al., 2014a; Theunissen et al., 2014b). However, the limited prior research in this area did not consider the language needs of children who are DHH, which could cause over-reporting on ADHD questionnaires that contain heavily language-based items. In fact, in previous studies conducted by Redmond and colleagues, the over-reporting of ADHD behaviors in children with developmental language disorder was minimized when removing language-based items from ADHD questionnaires (Redmond, 2020; Redmond et al., 2019; Redmond, 2002). We adopted this strategy of removing language-based items from ADHD questionnaires for a sample of children who are DHH. We hypothesized that children who are DHH would have more reported ADHD-behaviors than children who are typically developing, and that the number of attention-deficit behaviors would be correlated to their language abilities. Analyses revealed an effect of hearing status (whether children had typical hearing, wore cochlear implants or wore hearing aids) on overall inattention ratings and social/academic performance. Children who use cochlear implants had significantly lower ratings of inattention, meaning their parents reported fewer issues with inattention. In comparison, children who use hearing aids had more social/academic performance deficits than children with typical hearing. Differences in inattention scores for children with cochlear implants remained even when items biased towards language skills were removed from the measure, but differences in performance for children with hearing aids disappeared. Omnibus language scores across groups significantly correlated with academic and social outcomes, whereas parent report of fatigue significantly correlated with inattention and hyperactivity. These correlations do suggest possible multi-domain connections for children who are DHH between language, attention, and fatigue.

This first study demonstrates how, for children who are DHH, other domains of development may affect their experience of the world. Unlike prior work with children who have a primary language disorder (e.g., Redmond 2020), children who are DHH were not broadly overidentified as having ADHD-linked (i.e., executive functioning-related) behaviors based on their linguistic profile. However, the cognitive fatigue experienced by children who are DHH did relate to parent report of inattention and hyperactivity. The executive functioning domain and the language domain appear to interact within parent perceptions and interpretations of child behavior. This study, in combination with the work in children with primary language disorders, provides initial support that etiology may differentially affect the link between cognition and language.

Building upon the idea that executive functioning skills, like attention, play into the language learning abilities of children at risk for secondary language disorders, the question of how we can utilize these multi-domain relationships in intervention was addressed. Children with global delay (e.g., DS, Williams syndrome) have a particular weakness in expressive vocabulary (Caselli et al., 2008; Laws et al., 2015; Warren et al., 2008); however, relatively little research has evaluated best practices in vocabulary interventions for these children (Jordan et al., 2011). Word learning requires memory and attention, executive functioning skills that are also often delayed in children with DS (Daunhauer, 2014). Thus, the second study of this dissertation aimed to evaluate how an activity that may aid memory and attention, dance (a new, motor domain), could also influence language.

The theory of saliency posits that words become more memorable by adding components to them, such as motor movement (Wildt et al., 2019). The use of motor movement to help engage children and make words more salient created a three-domain intervention, allowing us to evaluate the use of a dynamic-systems theory-based approach to language treatment. The results from the dance-based intervention further added to our knowledge of the possible role of dynamic systems theory in the development of children with DS. Analyses revealed that preschool-aged children with and without DS gained significantly more words taught via movement than domain-specific intervention (i.e., traditional language therapy). Surprisingly, engagement, a context-dependent measure of attention in real-time, did not significantly differ across intervention types.

An important finding from the study was that word gains in domain-specific intervention were highly correlated with teacher reports of working memory, suggesting that success in a language-only intervention relies on a developed executive functioning system. Alternatively, the word gains in the dance-based intervention were not correlated to any executive functioning skill, suggesting that the use of the motor domain via dance makes words more salient even in individuals with less-developed executive functioning systems. These results further support multi-domain relationships for children with secondary language disorders in terms of language, executive functioning, and movement.

The third article considered the findings from the first and second articles and focused on answering a more overarching question about the relationship among domains for children with secondary language disorders, particularly when the diagnoses associated with those disorders have different expected effects on nonverbal cognition. The first study identified a relation between cognition and language in children who are DHH, and the second study identified a relation between motor movements and language learning in children with DS (and, possibly, a separate relation between executive functioning and language learning in a non-motor intervention context). Extant research has found connections between language and executive functioning (Kaczmarek et al., 2018; Sikora et al., 2019), language and physical activity (Mellor & Morini, 2023; Pruitt & Morini, 2021), and physical activity and executive functioning (Carson et al., 2016; Erickson et al., 2019); however, research that evaluates the interconnectivity for children with secondary language disorders between all three does not exist. The dynamic systems theory suggests that all three of these domains interact in a child's development (Smith & Thelen, 2003), and domain interactions may differ based on underlying disability diagnoses (i.e., individual constraints).

For the third article, a moderate-scale investigation into the interaction of domains for children with and without secondary language disorders was conducted. Measures included parent reports of participation in physical activities, parent reports of executive functioning deficit behaviors, performance-based executive functioning tasks, and an omnibus standardized language measure for the 75 participants. Significant group-based differences were found in the executive functioning and language domains, with children with DS having more reported difficulties with executive functioning and lower language scores than children who are typically developing and children who are DHH. Executive functioning scores significantly predicted language, especially when accounting for the variability in language scores due to differences among groups. Further, participation in structured physical activity moderated the effect of executive functioning on language skills. This final finding aligns with the dynamic systems theory of development and may act as a basis for the initial development of multi-modal interventions based in dynamic systems theories.

Although the three articles investigated different components of language, executive functioning, and physical activity for children at risk for secondary language disorders, they each grow scientific knowledge regarding dynamic systems theory and its application to children who may have atypical development.

Knowledge Gaps and Implications for Future Research and Practice

The three articles in this dissertation answered many questions regarding the inter-relations among domains of development while also opening the door to new questions to be answered through future investigations within this line of research.

The three studies all utilized parent and teacher report to quantify executive functioning skills, reflecting how our understanding of this domain is reliant on parent and teacher views of executive functioning. Prior work, indicates however, that adult-report skills and performance-based measures may not be equivalent: Ten Eycke and Dewey (2015) found that parent reports of executive function correlated with attention and academics; however, only performance-based measures of executive functioning correlated with motor skills. This suggests that parent reports may give a different picture of a child’s development than direct measures of executive functioning, especially as it pertains to multi-domain relationships. Additionally, when using parent reports with children who have disabilities, the correlation between parent report and performance-based measures of executive functioning skills is minimal (Gardiner et al., 2017;

Vriezen & Pigott, 2010). This gap in knowledge calls for further inquiry into the use of parent-report and performance measures in assessing executive functioning skills in children with disabilities.

The first inquiry would be a qualitative investigation into what parents (and teachers) understand regarding executive functioning skills and how this understanding could shape their reports, especially when considering non-academic behaviors. It is possible that different diagnoses influence parent interpretations of behavior in different ways. Recent studies have started to integrate qualitative methods into measure development, but these inquiries have focused on children with ADHD (Matza et al., 2017) and autism spectrum disorder (Ledger-Hardy, 2017).

A second line of inquiry to evaluate the executive functioning measurement gap would be to develop and validate performance-based measures for children with more severe language and learning difficulties. In the third study, fewer than half of the children with DS were able to complete the performance-based measure of executive functioning. Ten percent of the children who were DHH were also unable to complete the performance-based measure. In the second study, a performance-based measure of executive functioning was planned but abandoned due to participant behavior and inability to complete even the trial items. Earlier research also found difficulties using performance-based measures with the DS population (Daunhauer et al., 2017). If executive functioning gains in short time periods are to be measured and utilized in research evaluating multi-domain interventions, an appropriate performance-based measure is needed.

The three studies of this dissertation focused on the domains of executive functioning, motor, and language, but there are many other domains important to child development. Social emotional development has ties to movement and executive functioning (Gandotra et al., 2023), and preliminary data has found that motor skills play a moderating role on executive functioning outcomes and social-emotional skills (Hill et al., 2023). Measures for social-emotional wellness have already been developed (Varni, 2001; Waldman et al., 2021). These measures have not been used to investigate multi-domain correlations and interactions in children with disabilities, especially in regard to language. Social emotional development is a vital consideration in treating a child with a language disorder, and further knowledge regarding domain interactions is needed to gain a full picture.

This dissertation acts as a foundation for a line of research with the goal to explore the relation between multiple domains in children with language disorders to understand how the dynamic systems theory can be used to support better language outcomes. Thus, the overall future aim is improved intervention practices that enhance the effectiveness of speech-language therapy for children with language disorders. All three articles support the theory that a relationship between domains exists for children at risk for secondary language disorders. The second article, specifically, offers pilot data indicating how integrating the motor domain in language intervention can impact multiple domains regardless of level of need. Only a handful of intervention studies exist that pair movement with language-learning, and each reported significant gains in language skills (Duncan et al., 2017; Lund et al., 2019; Mellor & Morini, 2023; Pruitt & Morini, 2021; Toumpaniari et al., 2015); however, only one of these studies evaluated the usefulness of movement-based interventions on children with language disorders. There is building support for these interventions for gains in all domains: language, motor, cognition, and social-emotional skills; however, they do not exist for the children who actually need them. A primary suggestion is to develop interventions and conduct clinical trials assessing gains in multiple domains for multiple disability groups. The transition into translational research cannot occur without these foundational intervention trials. A second next step is a longitudinal study with children with secondary language disorders, methodically measuring each domain at regular time-points to evaluate how physical activity type, dose, and individual variables (e.g., age, IQ, disability type and severity) impact the effectiveness of intervention. No other longitudinal study of this nature exists, but it could answer many questions that cross-sectional or short-term intervention studies (such as the three articles in my dissertation) do not have the breadth of and depth to answer.

In conclusion, these three articles are a call to action for scientists and clinicians across fields. For scientists, studies in child development, especially in diverse populations, should consider multi-domains instead of singular domain studies. Clinicians should not be afraid to think across domains; perhaps a model of service delivery that considers multiple, interacting domains, such as seen in early intervention, could be beneficial to aging children. Dynamic systems theories of development are strongly supported in literature and recent research focuses on exploring the everyday implications of multiple-domain development for children who are typically developing. Expanding these studies to children with delays in development is vital and is possible. The time is now for innovative inquiries that build evidence for practice and support better outcomes for children with language needs.

REFERENCES

Abbeduto, L., Warren, S. F., & Conners, F. A. (2007). Language development in Down syndrome: From the prelinguistic period to the acquisition of literacy. *Mental retardation and developmental disabilities research reviews*, *13*(3), 247-261. https://doi.org/10.1002/mrdd.20158

Akshoomoff, N., Beaumont, J. L., Bauer, P. J., Dikmen, S. S., Gershon, R. C., Mungas, D., ... & Heaton, R. K. (2013). VIII. NIH Toolbox Cognition Battery (CB): Composite scores of crystallized, fluid, and overall cognition. Monographs of the Society for Research in Child Development, 78(4), 119-132. https://doi.org/10.1111/mono.12038

Aly, S. M., & Abonour, A. A. (2016). Effect of core stability exercise on postural stability in children with Down syndrome. *International Journal of Medical Research & Health Sciences, 5*(10), 213-222.

American Academy of Pediatrics (2020). *ADHD: Evaluation and Care*, ProQuest Ebook Central, http://ebookcentral.proquest.com/lib/tcu/detail.action?docID=6001634.

American Academy of Pediatrics, National Institute for Children's Health Quality, and McNeil Consumer and Specialty Pharmaceuticals (2002). *NICHQ Vanderbilt Assessment Scales.* https://www.nichq.org/resource/nichq-vanderbilt-assessment-scales.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596.

American Psychological Association. (n.d.). Cognition. In *APA dictionary of psychology*. Retrieved April 27, 2024, from https://dictionary.apa.org/cognition.Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child neuropsychology*, *8*(2), 71-82. https://doi.org/10.1076/chin.8.2.71.8724.

Anthony, C. J., & Ogg, J. (2020). Executive function, learning-related behaviors, and science growth from kindergarten to fourth grade. *Journal of Educational Psychology, 112*(8), 1563. https://doi.org/10.1037/edu0000447

Aram, D. M., & Nation, J. E. (1975). Patterns of language behavior in children with developmental language disorders. *Journal of Speech and Hearing Research*, *18*(2), 229-241. https://doi.org/10.1044/jshr.1802.229

Arumugam, A., Raja, K., Venugopalan, M., Chandrasekaran, B., Kovanur Sampath, K., Muthusamy, H., & Shanmugam, N. (2016). Down syndrome—A narrative review with a focus on anatomical features. *Clinical Anatomy, 29*(5), 568-577. https://doi.org/10.1002/ca.22672

Asker-Árnason, L., Wass, M., Gustafsson, F., & Sahlén, B. (2015). Reading comprehension and working memory capacity in children with hearing loss and cochlear implants or hearing aids. *The Volta Review*, *115*(1), 35-65.

Barkley, R. A. (2006). A theory of ADHD. *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment*, 297-334.

Becker, E., & Dusing, S. (2010). Participation is possible: A case report of integration into a community performing arts program. *Physiotherapy theory and practice*, *26*(4), 275-280. https://doi.org/10.3109/09593980903423137.

Bégel, V., Bachrach, A., Dalla Bella, S., Laroche, J., Clément, S., Riquet, A., & Dellacherie, D. (2021). Dance improves motor, cognitive, and social skills in children with developmental cerebellar anomalies. *The Cerebellum*, 1-16. https://doi.org/10.1007/s12311-021-01291-2

Berglund, E., Eriksson, M., & Johansson, I. (2001). Parental reports of spoken language skills in children with Down syndrome. *Journal of Speech, Language, and Hearing Research, 44*(1), 179-191. https://doi.org/10.1044/1092-4388(2001/016).

Bess, F. H., Davis, H., Camarata, S., & Hornsby, B. W. (2020). Listening-related fatigue in children with unilateral hearing loss. *Language, Speech, and Hearing Services in Schools*, *51*(1), 84-97. https://doi.org/10.1044/2019_LSHSS-OCHL-19-0017.

Bess, F. H., & Hornsby, B. W. (2014). Commentary: listening can be exhausting--fatigue in children and adults with hearing loss. *Ear and hearing*, *35*(6), 592–599. https://doi.org/10.1097/AUD.0000000000000099.

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental review*, *30*(4), 331-351. https://doi.org/10.1016/j.dr.2010.08.001

Bidzan-Bluma, I., & Lipowska, M. (2018). Physical activity and cognitive functioning of children: a systematic review. *International journal of environmental research and public health*, *15*(4), 800. https://doi.org/10.3390/ijerph15040800

Bishop, D. V., Snowling, M. J., Thompson, P. A., Greenhalgh, T., Catalise-2 Consortium, Adams, C., ... & house, A. (2017). Phase 2 of CATALISE: A multinational and multidisciplinary Delphi consensus study of problems with language development: Terminology. *Journal of Child Psychology and Psychiatry, 58*(10), 1068-1080. https://doi.org/10.1111/jcpp.12721

Bitsko, R. H., Claussen, A. H., Lichstein, J., Black, L. I., Jones, S. E., Danielson, M. L., ... & Meyer, L. N. (2022). Mental health surveillance among children—United States, 2013–2019. *MMWR supplements*, *71*(2), 1. https://doi.org/10.15585/mmwr.su7102a1

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual review of psychology*, *66*, 711-731. https://doi.org/10.1146/annurev-psych-010814-015221.

Blewitt, P., & Langan, R. (2016). Learning words during shared book reading: The role of extratextual talk designed to increase child engagement. *Journal of Experimental Child Psychology*, *150*, 404-410. https://doi.org/10.1016/j.jecp.2016.06.009.

Bloom, L., & Lahey, M. (1978). *Language development and language disorders.* Wiley. https://doi.org/10.7916/D8QZ2GQ5

Blum-Kulka, S. (2004). The role of peer interaction in later pragmatic development. *Language development across childhood and adolescence*, 191-210.

Bogue, E. L., DeThorne, L. S., & Schaefer, B. A. (2014). A psychometric analysis of childhood vocabulary tests. *Contemporary Issues in Communication Science and Disorders*, *41*(Spring), 55-69. https://doi.org/10.1044/cicsd_41_S_55

Boksem, M. A., & Tops, M. (2008). Mental fatigue: Costs and benefits. *Brain Research Reviews*, *59*(1), 125–139. https://doi.org/10.1016/j.brainresrev.2008.07.001

Breland, L., Lowenstein, J. H., & Nittrouer, S. (2022). Disparate oral and written language abilities in adolescents with cochlear implants: Evidence from narrative samples. *Language, Speech, and Hearing Services in Schools*, *53*(1), 193-212. https://doi.org/10.1044/2021_LSHSS-21-00062

Brown, L., Sherbenou, R.J., & Johnsen, S.K. (2010). *Test of Nonverbal Intelligence* (4th ed.). [Measurement instrument]. Austin, TX.: PRO-ED.

Buchanan, L., & Westbury, C. (2001). Characterizing semantic space: Neighborhood effects in word recognition. *Psychonomic Bulletin & Review, 8*, 531–544. https://doi.org/10.3758/BF03196189

Cadenas-Sanchez, C., Migueles, J. H., Verdejo-Román, J., Erickson, K. I., Esteban-Cornejo, I., Catena, A., & Ortega, F. B. (2023). Physical activity, sedentary time, and fitness in relation to brain shapes in children with overweight/obesity: Links to intelligence. *Scandinavian Journal of Medicine & Science in Sports, 33*(3), 319-330. https://doi.org/10.1111/sms.14263

Calabretta, B. T., Schneider, J. L., & Iverson, J. M. (2022). Bidding on the go: Links between walking, social actions, and caregiver responses in infant siblings of children with autism spectrum disorder. *Autism Research*, *15*(12), 2324-2335. https://doi.org/10.1002/aur.2830

Camarata, S., Werfel, K., Davis, T., Hornsby, B. W. Y., & Bess, F. H. (2018). Language abilities, phonological awareness, reading skills, and subjective fatigue in school-age children with mild to moderate hearing loss. *Exceptional Children, 84*(4), 420–436. https://doi.org/10.1177/0014402918773316.

Capio, C. M., Mak, T. C. T., Tse, M. A., & Masters, R. S. W. (2018). Fundamental movement skills and balance of children with Down syndrome. *Journal of Intellectual Disability Research, 62*(3), 225-236. https://doi.org/10.1111/jir.12458.

Carpenter, M. G., & Campos, J. L. (2020). The effects of hearing loss on balance: a critical review. *Ear and hearing, 41*, 107S-119S. https://doi.org/10.1097/AUD.0000000000000929.

Carson, V., Hunter, S., Kuzik, N., Wiebe, S. A., Spence, J. C., Friedman, A., ... & Hinkley, T. (2016). Systematic review of physical activity and cognitive development in early childhood. *Journal of Science and Medicine in Sport*, *19*(7), 573-578. https://doi.org/10.1016/j.jsams.2015.07.011.

Caselli, M. C., Monaco, L., Trasciani, M., & Vicari, S. (2008). Language in Italian children with Down syndrome and with specific language impairment. *Neuropsychology*, *22*(1), 27. https://doi.org/10.1037/0894-4105.22.1.27

Catts, H. W., Fey, M. E., Tomblin, J. B., & Zhang, X. (2002). A longitudinal investigation of reading outcomes in children with language impairments. *Journal of Speech, Language, and Hearing Research, 45* (6), 1142-1157. https://doi.org/10.1044/1092-4388(2002/093)

Centers for Disease Control and Prevention (n.d). *1991-2021 High School Youth Risk Behavior Survey Data*. Available at http://yrbs-explorer.services.cdc.gov/. Accessed on April 27, 2024.

Centers for Disease Control. (2021). *Milestone Moments* [Pamphlet]. https://www.cdc.gov/ncbddd/actearly/pdf/parents_pdfs/milestonemomentseng508.pdf

Česnaitienė, V., Drozdova-Statkeviciene, M., Levin, O., Ossowsky, M. Z., & Masiulis, N. (2022). Does physical activity improve an interaction between motor control and cognitive functions in elderly?. In *European Journal of Public Health: 2022 HEPA Europe Conference: An Ecosystem Approach to Health-Enhancing Physical Activity Promotion* (Vol. 32, No. s2). Oxford University Press (OUP).

Chaddock, L., Pontifex, M. B., Hillman, C. H., & Kramer, A. F. (2011). A review of the relation of aerobic fitness and physical activity to brain structure and function in children. *Journal of the international Neuropsychological Society*, *17*(6), 975-985. https://doi.org/10.1017/S1355617711000567.

Cherriere, C., Martel, M., Fortin, S., Raymond, M. J., Veilleux, L. N., & Lemay, M. (2020). An adapted dance program for children with Charcot-Marie-Tooth disease: An exploratory study. *Journal of Bodywork and Movement Therapies*, *24*(2), 85-91. https://doi.org/10.1016/j.jbmt.2019.09.009.

Ching, T. Y., Cupples, L., Leigh, G., Hou, S., & Wong, A. (2021). Predicting quality of life and behavior and emotion from functional auditory and pragmatic language abilities in 9-year-old deaf and hard-of-hearing children. *Journal of Clinical Medicine*, *10*(22), 5357. https://doi.org/10.3390/jcm10225357.

Chow, J. C., & Hollo, A. E. (2022). Language skills of students with emotional and behavioral disorders. *Intervention in School and Clinic*, *58*(1), 46-50. https://doi.org/10.1177/10534512211047584.

Chow, J. C., & Wehby, J. H. (2018). Associations between language and problem behavior: A systematic review and correlational meta-analysis. *Educational Psychology Review*, *30*(1), 61-82. https://doi.org/10.1007/s10648-016-9385-z.

Chow, J. C., & Wehby, J. H. (2019). Profiles of problem behavior in children with varying language ability. *Journal of Emotional and Behavioral Disorders*, *27*(2), 110-118. https://doi.org/10.1177/1063426617733714.

Clark, C. A., Sheffield, T. D., Wiebe, S. A., & Espy, K. A. (2013). Longitudinal associations between executive control and developing mathematical competence in preschool boys and girls. *Child Development*, *84*(2), 662-677. https://doi.org/10.1111/j.1467-8624.2012.01854.x

Clearfield, M. W. (2011). Learning to walk changes infants' social interactions. *Infant Behavior and Development*, *34*(1), 15-25. https://doi.org/10.1016/j.infbeh.2010.04.008

Clearfield, M. W., Osborne, C. N., & Mullen, M. (2008). Learning by looking: Infants' social looking behavior across the transition from crawling to walking. *Journal of experimental child psychology*, *100*(4), 297-307. https://doi.org/10.1016/j.jecp.2008.03.005.

Cohen, N., Barwick, M., Horodezky, M., Vallance, D., & Im, N. (1998). Language, achievement, and cognitive processing of psychiatrically disturbed children with previously unidentified and unsuspected language impairments. *Journal of Child Psychology and Psychiatry, 39*, 865–877. https://doi.org/10.1111/1469-7610.00387.

Conway, C. M., & Pisoni, D. B. (2008). Neurocognitive basis of implicit learning of sequential structure and its relation to language processing. *Annals of the New York Academy of Sciences*, *1145*(1), 113-131. https://doi.org/10.1196/annals.1416.009.

Conway, C. M., Pisoni, D. B., & Kronenberger, W. G. (2009). The importance of sound for cognitive sequencing abilities: The auditory scaffolding hypothesis. *Current Directions in Psychological Science*, *18*(5), 275-279. https://doi.org/10.1111/j.1467-8721.2009.01651.x.

Coret, M. C., & McCrimmon, A. W. (2015). Test review: Wiig, EH, Semel, E., & Secord, WA (2013). Clinical evaluation of language fundamentals–fifth edition (CELF-5). Journal of Psychoeducational Assessment, 33(5), 495-500. https://doi.org/10.1177/0734282914557616.

Daunhauer, L. A., Fidler, D. J., Hahn, L., Will, E., Lee, N. R., & Hepburn, S. (2014). Profiles of everyday executive functioning in young children with Down syndrome. *American journal on intellectual and developmental disabilities*, *119*(4), 303-318. https://doi.org/10.1352/1944-7558-119.4.303.

Daunhauer, L. A., Gerlach-McDonald, B., Will, E., & Fidler, D. J. (2017). Performance and ratings based measures of executive function in school-aged children with Down syndrome. *Developmental Neuropsychology*, *42*(6), 351-368. https://doi.org/10.1080/87565641.2017.1360303.

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., ... & Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized, controlled trial. *Health psychology*, *30*(1), 91. https://psycnet.apa.org/doi/10.1037/a0021766.

DeLuca, Z. W., & Rupp, K. (2022). Physical activity, sports participation, and psychosocial health in adolescents with hearing loss. *Journal of Adolescent Health*, *71*(5), 635-641. https://doi.org/10.1016/j.jadohealth.2022.05.011.

Dimitrova, N., Özçalışkan, Ş., & Adamson, L. B. (2016). Parents' translations of child gesture facilitate word learning in children with autism, Down syndrome and typical development. *Journal of Autism and Developmental Disorders*, *46*, 221-231. https://doi.org/10.1007/s10803-015-2566-7.

Dollaghan, C. A., Campbell, T. F., Paradise, J. L., Feldman, H. M., Janosky, J. E., Pitcairn, D. N., & Kurs-Lasky, M. (1999). Maternal education and measures of early speech and language. *Journal of Speech, Language, and Hearing Research*, *42*(6), 1432-1443. https://doi.org/10.1044/jslhr.4206.1432.

Dunn, D. M. (2019). Peabody Picture Vocabulary Test (5th ed.) [Measurement instrument]. Bloomington, MN: NCS Pearson.

Eadie, P. A., Fey, M. E., Douglas, J. M., & Parsons, C. L. (2002). Profiles of grammatical morphology and sentence imitation in children with specific language impairment and Down syndrome. *Journal of Speech, Language, and Hearing Research*, *45*, 720-732. https://doi.org/10.1044/1092-4388(2002/058).

Education Code,42 TEC §42.003 (2014). https://statutes.capitol.texas.gov/StatutesByDate.aspxcode=ED&level=SE&value=42.003 &date=6/28/2014

Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., ... & Powell, K. E. (2019). Physical activity, cognition, and brain outcomes: a review of the 2018 physical activity guidelines. *Medicine and Science in Sports and Exercise*, *51*(6), 1242. https://doi.org/10.1249/MSS.0000000000001936.

Fedewa, A. L., & Ahn, S. (2011). The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis. *Research quarterly for exercise and sport*, *82*(3), 521-535. https://doi.org/10.1080/02701367.2011.10599785.

Fitzpatrick, E. M., Gaboury, I., Durieux-Smith, A., Coyle, D., Whittingham, J., & Nassrallah, F.(2019). Auditory and language outcomes in children with unilateral hearing loss. *Hearing Research*, *372*, 42–51. https://doi.org/10.1016/j.heares.2018.03.015.

Fletcher, H., & Buckley, S. (2002). Phonological awareness in children with Down syndrome. *Down Syndrome Research and Practice*, *8*(1), 11-18. https://doi.org/10.3104/reports.123.

Foy, J. G., & Mann, V. A. (2014). Bilingual children show advantages in nonverbal auditory executive function task. International Journal of Bilingualism, 18(6), 717-729. https://doi.org/10.1177/1367006912472263.

Frizelle, P., Thompson, P. A., Duta, M., & Bishop, D. V. M. (2019). The understanding of complex syntax in children with Down syndrome. *Wellcome open research*, *3*, 140. https://doi.org/10.12688/wellcomeopenres.14861.2

Gallaudet Research Institute. (2013). G. Regional and national summary report of data from the 2009-10 Annual Survey of Deaf and Hard of Hearing Children and Youth. Washington, DC: Gallaudet University; http://research.gallaudet.edu/Demographics/2012_National_Summary.pdf.

Gandotra, A., Kotyuk, E., Bizonics, R., Khan, I., Petánszki, M., Kiss, L., ... & Cserjesi, R. (2023). An exploratory study of the relationship between motor skills and indicators of cognitive and socio-emotional development in preschoolers. *European Journal of Developmental Psychology*, *20*(1), 50-65. https://doi.org/10.1080/17405629.2022.2028617.

Gardiner, E., Hutchison, S. M., Müller, U., Kerns, K. A., & Iarocci, G. (2017). Assessment of executive function in young children with and without ASD using parent ratings and computerized tasks of executive function. *The Clinical Neuropsychologist*, *31*(8), 1283-1305. https://doi.org/10.1080/13854046.2017.1290139.

Garner, J. K. (2009). Conceptualizing the relations between executive functions and self-regulated learning. *The Journal of Psychology, 143*(4), 405-426. https://doi.org/10.3200/JRLP.143.4.405-426.

Geers, A. E., Nicholas, J., Tobey, E., & Davidson, L. (2016). Persistent language delay versus late language emergence in children with early cochlear implantation. *Journal of Speech, Language, and Hearing Research*, *59*(1), 155-170. https://doi.org/10.1044/2015_JSLHR-H-14-0173.

Geers, A. E., & Sedey, A. L. (2011). Language and verbal reasoning skills in adolescents with 10 or more years of cochlear implant experience. *Ear and Hearing*, *32*(1 Suppl), 39S. https://doi.org/10.1097/AUD.0b013e3181fa41dc.

Gershon, R. C., Cella, D., Fox, N. A., Havlik, R. J., Hendrie, H. C., & Wagster, M. V. (2010). Assessment of neurological and behavioural function: the NIH Toolbox. The Lancet Neurology, 9(2), 138-139. https://doi.org/10.1016/S1474-4422(09)70335-7.

Gioia G. A., Isquith P. K., Guy S. C., Kenworthy L. (2015). Behavior Rating Inventory of Executive Function®, Second Edition (BRIEF®2). [Measurement instrument]. Lutz, FL: PAR Inc.

Goodman, R., Ford, T., Simmons, H., Gatward, R. & Meltzer, H. (2000). Using the Strengths and Difficulties Questionnaire (SDQ) to screen for psychiatric disorders in a community sample. *British Journal of Psychiatry*, *177*, 534–539. https://doi.org/10.1192/bjp.177.6.534.

Gordon-Murer, C., Stöckel, T., Sera, M., & Hughes, C. M. (2021). Developmental differences in the relationship between sensorimotor and executive functions. *Frontiers in Human Neuroscience*, 467. https://doi.org/10.3389/fnhum.2021.714828.

Grieco, J., Pulsifer, M., Seligsohn, K., Skotko, B., & Schwartz, A. (2015, June). Down Syndrome: Cognitive and behavioral functioning across the lifespan. In *American Journal of Medical Genetics Part C: Seminars in Medical Genetics* (Vol. 169, No. 2, pp. 135-149). https://doi.org/10.1002/ajmg.c.31439.

Guzmán-Muñoz, E. E., Gutiérrez-Navarro, L. B., & Miranda-Díaz, S. E. (2017). Postural control in children, adolescents and adults with Down syndrome. *International Medical Review on Down Syndrome, 21*(1), 12-16. https://doi.org/10.1016/j.sdeng.2016.09.003.

Hall, M. L., Eigsti, I. M., Bortfeld, H., & Lillo-Martin, D. (2018). Executive function in deaf children: Auditory access and language access. *Journal of Speech, Language, and Hearing Research*, *61*(8), 1970-1988. https://doi.org/10.1044/2018_JSLHR-L-17-0281.

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—A metadata-driven methodology and work flow process for providing translational research informatics support. Journal of Biomedical Informatics, 42(2), 377–381. https://doi.org/10.1016/j.jbi.2008.08.010.

Haywood, K. M., & Getchell, N. (2021). *Life span motor development*. Human kinetics.

Hendrickson, N. K., & McCrimmon, A. W. (2019). Test Review: behavior rating inventory of executive function®, second edition (BRIEF®2) by Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. Canadian Journal of School Psychology, 34(1), 73–78. https://doi.org/10.1177/0829573518797762

Hessling, A., & Schuele, C. M. (2020). Individualized narrative intervention for school-age children with specific language impairment. *Language, Speech, and Hearing Services in Schools*, *51*(3), 687-705. https://doi.org/10.1044/2019_LSHSS-19-00082.

Hicks, C. B., & Tharpe, A. M. (2002). Listening effort and fatigue in school-age children with and without hearing loss. *Journal of Speech, Language, and Hearing Research, 45*(3), 573-584. https://doi.org/10.1044/1092-4388(2002/046).

Hornsby, B. W., Werfel, K., Camarata, S., & Bess, F. H. (2014). Subjective fatigue in children with hearing loss: Some preliminary findings. *American Journal of Audiology, 23*(1), 129-134. https://doi.org/10.1044/1059-0889(2013/13-0017).

Huang, C. C., Lu, S., Rios, J., Chen, Y., Stringham, M., & Cheung, S. (2020). Associations between mindfulness, executive function, social-emotional skills, and quality of life among Hispanic children. *International Journal of Environmental Research and Public Health*, *17*(21), 7796. https://doi.org/10.3390/ijerph17217796.

Iverson, J. M. (2010). Developing language in a developing body: The relationship between motor development and language development. *Journal of child language*, *37*(2), 229-261. https://doi.org/10.1017/S0305000909990432.

Iverson, J. M. (2021). Developmental variability and developmental cascades: Lessons from motor and language development in infancy. *Current Directions in Psychological Science*, *30*(3), 228-235. https://doi.org/10.1177/0963721421993822.

Iverson, J. M., West, K. L., Schneider, J. L., Plate, S. N., Northrup, J. B., & Britsch, E. R. (2023). Early development in autism: How developmental cascades help us understand the emergence of developmental differences. In *Advances in Child Development and Behavior* (Vol. 64, pp. 109-134). JAI. https://doi.org/10.1016/bs.acdb.2022.10.005.

Jackson, M. I., Kiernan, K., & McLanahan, S. (2017). Maternal education, changing family circumstances, and children's skill development in the United States and UK. *The ANNALS of the American Academy of Political and Social Science*, *674*(1), 59-84. https://doi.org/10.1177/0002716217729471.

Jain, P. D., Nayak, A., Karnad, S. D., & Doctor, K. N. (2022). Gross motor dysfunction and balance impairments in children and adolescents with Down syndrome: a systematic review. *Clinical and Experimental Pediatrics*, *65*(3), 142. https://doi.org/10.3345/cep.2021.00479.

Jordan, S., Miller, G. L., & Riley, K. (2011). Enhancements of dialogic reading for young children with Down syndrome. *Young Exceptional Children, 14*(4), 19-30. https://doi.org/10.1177/1096250611425025.

Kaczmarek, I., Jabłoński, S., Kleka, P., & Steinborn, B. (2018). Efficiency of executive functions and literacy among children with specific language impairment. *Psychology of Language and Communication*, *22*(1), 307-327. https://doi.org/10.2478/plc-2018-0014.

Kaiser, A. P., Chow, J. C., & Cunningham, J. E. (2022). A case for early language and behavior screening: Implications for policy and child development. *Policy Insights from the Behavioral and Brain Sciences*, *9*(1), 120-128. https://doi.org/10.1177/23727322211068886.

Kapa, L. L., & Erikson, J. A. (2019, August). Variability of executive function performance in preschoolers with developmental language disorder. In *Seminars in Speech and Language* (Vol. 40, No. 04, pp. 243-255). Thieme Medical Publishers. https://doi.org/10.1055/s-0039-1692723.

Kapa, L. L., Plante, E., & Doubleday, K. (2017). Applying an integrative framework of executive function to preschoolers with specific language impairment. *Journal of Speech, Language, and Hearing Research, 60*(8), 2170–2184. https://doi.org/10.1044/2017_JSLHR-L-16-0027.

Karasik, L. B., Tamis-LeMonda, C. S., & Adolph, K. E. (2011). Transition from crawling to walking and infants' actions with objects and people. *Child development*, *82*(4), 1199-1209. https://doi.org/10.1111/j.1467-8624.2011.01595.x.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry*, *62*(6), 593-602. https://doi.org/10.1001/archpsyc.62.6.593.

Kevan, F. (2003). Challenging behaviour and communication difficulties. *British Journal of Learning Disabilities*, 31(2), 75–80. https://doi.org/10.1046/j.1468-3156.2003.00226.x.

Khanna, M. M., & Boland, J. E. (2010). Children's use of language context in lexical ambiguity resolution. *Quarterly Journal of Experimental Psychology*, *63*(1), 160-193. https://doi.org/10.1080/17470210902866664.

Khodaverdi, Z., Moreau, D., & Garber, C. E. (2022). Is there an effective dose of aerobic exercise associated with better executive function in youth with attention deficit hyperactivity disorder?. *Child Neuropsychology*, *28*(5), 569-596. https://doi.org/10.1080/09297049.2021.1992378.

Kingston, Ú., Adamakis, M., & Costa, J. (2020). Acute effects of physical education, structured play, and unstructured play in children's executive functions in primary school. *Journal of Physical Education and Sport*, *20*(6), 3260-3266. doi: 10.7752/jpes.2020.s6442

Kristensen, K., Lorenz, K. M., Zhou, X., Piro-Gambetti, B., Hartley, S. L., Godar, S. P., ... & Litovsky, R. Y. (2022). Language and executive functioning in young adults with Down syndrome. *Journal of Intellectual Disability Research*, *66*(1-2), 151-161. https://doi.org/10.1111/jir.12868.

Kronenberger, W. G., & Pisoni, D. B. (2018). Neurocognitive functioning in deaf children with cochlear implants. *Evidence-Based Practice in Deaf Education*, 363-396. https://doi.org/10.1093/oso/9780190880545.003.0016

Kronenberger, W. G., Pisoni, D. B., Henning, S. C., & Colson, B. G. (2013). Executive functioning skills in long-term users of cochlear implants: A case control study. *Journal of Pediatric Psychology*, *38*(8), 902-914. https://doi.org/10.1093/jpepsy/jst034.

Kronenberger, W. G., Xu, H., & Pisoni, D. B. (2020). Longitudinal development of executive functioning and spoken language skills in preschool-aged children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *63*(4), 1128-1147. https://doi.org/10.1044/2019_JSLHR-19-00247.

Lakes, K. D., & Hoyt, W. T. (2004). Promoting self-regulation through school-based martial arts training. *Journal of Applied Developmental Psychology*, *25*(3), 283-302. https://doi.org/10.1016/j.appdev.2004.04.002.

Lakes, K. D., Sharp, K., Grant-Beuttler, M., Neville, R., Haddad, F., Sunico, R., ... & Radom-Aizik, S. (2019). A six week therapeutic ballet intervention improved gait and inhibitory control in children with cerebral palsy—a pilot study. *Frontiers in Public Health*, *7*, 137. https://doi.org/10.3389/fpubh.2019.00137.

Lauteslager, P. E. M., Vermeer, A., & Helders, P. J. M. (1998). Disturbances in the motor behaviour of children with Down's syndrome: the need for a theoretical framework. *Physiotherapy, 84*(1), 5-13. https://doi.org/10.1016/S0031-9406(05)65896-8.

Laws, G., Briscoe, J., Ang, S. Y., Brown, H., Hermena, E., & Kapikian, A. (2015). Receptive vocabulary and semantic knowledge in children with SLI and children with Down syndrome. *Child Neuropsychology*, *21*(4), 490-508. https://doi.org/10.1080/09297049.2014.917619.

Laws, G., Brown, H., & Main, E. (2016). Reading comprehension in children with Down syndrome. *Reading and Writing, 29*(1), 21-45. https://doi.org/10.1007/s11145-015-9578-8.

Ledger-Hardy, L. (2017). *Developing and Piloting a New Parent-Report Measure of Executive Function for Children with Autism Spectrum Disorder (ASD)* (Doctoral dissertation, UCL (University College London)).

Leezenbaum, N. B., & Iverson, J. M. (2019). Trajectories of posture development in infants with and without familial risk for autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *49*, 3257-3277. https://doi.org/10.1007/s10803-019-04048-3.

Li, K. Z., Roudaia, E., Lussier, M., Bherer, L., Leroux, A., & McKinley, P. A. (2010). Benefits of cognitive dual-task training on balance performance in healthy older adults. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *65*(12), 1344-1352. https://doi.org/10.1093/gerona/glq151.

Lieberman H. R. (2007). Cognitive methods for assessing mental energy. *Nutritional Neuroscience*, *10*(5-6), 229–242. https://doi.org/10.1080/10284150701722273.

Lim, C. Y., & In, J. (2021). Considerations for crossover design in clinical study. *Korean Journal of Anesthesiology*, *74*(4), 293-299. https://doi.org/10.4097/kja.21165.

Liogier d'Ardhuy, X., Edgin, J. O., Bouis, C., De Sola, S., Goeldner, C., Kishnani, P., ... & Khwaja, O. (2015). Assessment of cognitive scales to examine memory, executive function and language in individuals with Down syndrome: Implications of a 6-month observational study. *Frontiers in Behavioral Neuroscience, 9*, 300. https://doi.org/10.3389/fnbeh.2015.00300.

Loveall, S. J., Channell, M. M., Abbeduto, L., & Conners, F. A. (2019). Verb production by individuals with Down syndrome during narration. *Research in Developmental Disabilities*, *85*, 82-91. https://doi.org/10.1016/j.ridd.2018.11.007.

Loveall, S. J., Channell, M. M., Phillips, B. A., Abbeduto, L., & Conners, F. A. (2016). Receptive vocabulary analysis in Down syndrome. *Research in developmental disabilities*, *55*, 161-172. https://doi.org/10.1016/j.ridd.2016.03.018.

Loveall, S. J., Conners, F. A., Tungate, A. S., Hahn, L. J., & Osso, T. (2017). A cross-sectional analysis of executive function in Down Syndrome from 2 to 35 years. *Journal of Intellectual Disability Research*, *61*(9), 877-887. https://doi.org/10.1111/jir.12396.

Lund, E. (2016). Vocabulary knowledge of children with cochlear implants: A meta-analysis. *Journal of Deaf Studies and Deaf Education*, *21*(2), 107-121. https://doi.org/10.1093/deafed/env060.

Lund, E. (2020). The relation between vocabulary knowledge and phonological awareness in children with cochlear implants. *Journal of Speech, Language, and Hearing Research, 63*(7), 2386-2402. https://doi.org/10.1044/2020_JSLHR-19-00259.

Lund, E., Brock, N., & Werfel, K. L. (2022). Location effects on spoken language and literacy for children who are DHH. *Journal of Deaf Studies and Deaf Education*, *27*(1), 48-61. https://doi.org/10.1093/deafed/enab030.

Lund, E., Douglas, W. M., & Schuele, C. M. (2015). Semantic richness and word learning in children with hearing loss who are developing spoken language: A single case design study. *Deafness and Education International, 17*, 163–175. https://doi.org/10.1179/1557069X15Y.0000000004

Lund, E., Young, A., & Yarbrough, R. (2020). The effects of co-treatment on concept development in children with Down Syndrome. *Communication Disorders Quarterly*, *41*(3), 176-187. https://doi.org/10.1177/1525740119827264.

Luo, X., Herold, F., Ludyga, S., Gerber, M., Kamijo, K., Pontifex, M. B., ... & Zou, L. (2023). Association of physical activity and fitness with executive function among preschoolers. *International Journal of Clinical and Health Psychology*, *23*(4), 100400. https://doi.org/10.1016/j.ijchp.2023.100400.

Mahy, J., Shields, N., Taylor, N. F., & Dodd, K. J. (2010). Identifying facilitators and barriers to physical activity for adults with Down syndrome. *Journal of Intellectual Disability Research*, *54*(9), 795-805. https://doi.org/10.1111/j.1365-2788.2010.01308.x.

Majorek, M., Tüchelmann, T., & Heusser, P. (2004). Therapeutic eurythmy—movement therapy for children with attention deficit hyperactivity disorder (ADHD): A pilot study. *Complementary Therapies in Nursing and Midwifery*, *10*(1), 46-53. https://doi.org/10.1016/S1353-6117(03)00087-8.

Manjunath, N. K., & Telles, S. (2001). Improved performance in the Tower of London test following yoga. *Indian Journal of Physiology and Pharmacology*, *45*(3), 351-354.

Mann, T. D., Hund, A. M., Hesson-McInnis, M. S., & Roman, Z. J. (2017). Pathways to school readiness: Executive functioning predicts academic and social–emotional aspects of school readiness. *Mind, Brain, and Education*, *11*(1), 21-31. https://doi.org/10.1111/mbe.12134.

Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental science*, *11*(3), F9-F16. https://doi.org/10.1111/j.1467-7687.2008.00671.x.

Marini, A., Piccolo, B., Taverna, L., Berginc, M., & Ozbič, M. (2020). The complex relation between executive functions and language in preschoolers with Developmental Language Disorders. *International Journal of Environmental Research and Public Health*, *17*(5), 1772. https://doi.org/10.3390/ijerph17051772.

Martin, N., & Brownell, R. (2011). Expressive One-Word Picture Vocabulary Test (4th ed.). [Measurement instrument]. Novato: Academic Therapy Publications.

Martin, G. E., Klusek, J., Estigarribia, B., & Roberts, J. E. (2009). Language characteristics of individuals with Down syndrome. *Topics in language disorders*, *29*(2), 112. https://doi.org/10.1097%2Ftld.0b013e3181a71fe1.

Mattingly, J., Werfel, K. L., & Lund, E. (2023). Parent-Reported Attention-Deficit/Hyperactivity Disorder–Linked Behaviors, Fatigue, and Language in Children Who Are Deaf and Hard of Hearing. *Perspectives of the ASHA Special Interest Groups, 8*(6), 1409-1421. https://doi.org/10.1044/2023_PERSP-23-00086.

Mattingly, J., Yarbrough, R., & Lund, E. (Submitted). Effects of dance on word learning in preschool children with Down Syndrome. [Manuscript in preparation]. Harris College, Texas Christian University.

Matza, L. S., Margolis, M. K., Deal, L. S., Farrand, K. F., & Erder, M. H. (2017). Challenges of developing an observable parent-reported measure: a qualitative study of functional impact of ADHD in children. *Value in Health*, *20*(6), 828-833. https://doi.org/10.1016/j.jval.2017.02.010.

Mavilidi, M. F., Okely, A. D., Chandler, P., Cliff, D. P., & Paas, F. (2015). Effects of integrated physical exercises and gestures on preschool children's foreign language vocabulary learning. *Educational psychology review*, *27*, 413-426. https://doi.org/10.1007/s10648-015-9337-z.

Mazaheryazdi, M., Moossavi, A., Sarrafzadah, J., Talebian, S., & Jalaie, S. (2017). Study of the effects of hearing on static and dynamic postural function in children using cochlear implants. *International journal of pediatric otorhinolaryngology, 100*, 18-22. https://doi.org/10.1016/j.ijporl.2017.06.002.

McCauley, R. J., & Swisher, L. (1984). Use and misuse of norm-referenced test in clinical assessment: A hypothetical case. *Journal of Speech and Hearing Disorders*, *49*(4), 338-348. https://doi.org/10.1044/jshd.4904.338.

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly*, *28*(2), 314-324. https://doi.org/10.1016/j.ecresq.2012.07.008.

McWilliam, R. A., & Casey, A. M. (2008). Engagement of every child in the preschool classroom. Baltimore, MD: Paul H. Brookes Publishing Company.

Mehralitabar, H., Sheikh, M., & Hemayat-Talab, R. (2016). Effect of a selective physical training on balance of children with Down syndrome. *International Journal of Sport Studies, 6*, 147-151.

Mellor, L., & Morini, G. (2023). Examining the relation between exercise and word learning in preschool-age children. *Journal of Speech, Language, and Hearing Research*, *66*(3), 1018-1032. https://doi.org/10.1044/2022_JSLHR-22-00250.

Melo, R. D. S., Marinho, S. E. D. S., Freire, M. E. A., Souza, R. A., Damasceno, H. A. M., & Raposo, M. C. F. (2017). Static and dynamic balance of children and adolescents with sensorineural hearing loss. *Einstein (São Paulo)*, *15*, 262-268. https://doi.org/10.1590/S1679-45082017AO3976.

Mendelsohn, A. L., Mogilner, L. N., Dreyer, B. P., Forman, J. A., Weinstein, S. C., Broderick, M., ... & Napier, C. (2001). The impact of a clinic-based literacy intervention on language development in inner-city preschool children. *Pediatrics*, *107*(1), 130-134. https://doi.org/10.1542/peds.107.1.130.

Michael, S. E., Ratner, N. B., & Newman, R. (2012). Verb comprehension and use in children and adults with Down syndrome. *Journal of Speech, Language, and Hearing Research, 55*(6), 1736-1749. https://doi.org/10.1044/1092-4388(2012/11-0050).

Mlincek, M. M., Roemer, E. J., Kraemer, C., & Iverson, J. M. (2022). Posture matters: Object manipulation during the transition to arms-free sitting in infants at elevated vs. typical likelihood for autism spectrum disorder. *Physical & occupational therapy in pediatrics*, *42*(4), 351-365. https://doi.org/10.1080/01942638.2022.2027845.

Moeller, M. P., McCleary, E., Putman, C., Tyler-Krings, A., Hoover, B., & Stelmachowicz, P. (2010). Longitudinal development of phonology and morphology in children with late-identified mild-moderate sensorineural hearing loss. *Ear and hearing*, *31*(5), 625. https://doi.org/10.1097/AUD.0b013e3181df5cc2.

Moraru, C., Hodorcă, R.M., & Vasilescu, D. (2014). The role of gymnastics and dance in rehabilitating motor capacities in children with Down syndrome. *Interdisciplinary Journal of Physical Education and Sport*,14, 102–112.

Most, T., Shina-August, E., & Meilijson, S. (2010). Pragmatic abilities of children with hearing loss using cochlear implants or hearing aids compared to hearing children. *Journal of Deaf Studies and Deaf Education*, *15*(4), 422-437. https://doi.org/10.1093/deafed/enq032.

Mulé, D., Jeger, I., Dötsch, J., Breido, F., Ferrari, N., & Joisten, C. (2022). Correlation between Language Development and Motor Skills, Physical Activity, and Leisure Time Behaviour in Preschool-Aged Children. *Children*, *9*(3), 431. https://doi.org/10.3390/children9030431.

Næss, K. A. B., Melby-Lervåg, M., Hulme, C., & Lyster, S. A. H. (2012). Reading skills in children with Down Syndrome: A meta-analytic review. *Research in Developmental Disabilities*, *33*(2), 737-747. https://doi.org/10.1016/j.ridd.2011.09.019.

Næss, K. A. B., Ostad, J., & Nygaard, E. (2021). Differences and similarities in predictors of expressive vocabulary development between children with Down syndrome and young typically developing children. *Brain Sciences*, *11*(3), 312. https://doi.org/10.3390/brainsci11030312.

Nation, K., Clarke, P., Marshall, C. M., & Durand, M. (2004). Hidden language impairments in children. *Journal of Speech, Language, and Hearing Research, 47*(1), 199-211. https://doi.org/10.1044/1092-4388(2004/017).

Nejati, V. (2021). Balance-based attentive rehabilitation of attention networks (BARAN) improves executive functions and ameliorates behavioral symptoms in children with ADHD. *Complementary Therapies in Medicine*, *60*, 102759. https://doi.org/10.1016/j.ctim.2021.102759.

Nelson, J. (2015). Special needs and dance: An insider's perspective. *Journal of Dance Education*, *15*(3), 110-115. https://doi.org/10.1080/15290824.2015.1061399.

Nepal, A. K. (2018). What matters more for child health: A father's education or mother's education?. *World Development Perspectives*, *10*, 24-33. https://doi.org/10.1016/j.wdp.2018.09.002.

Newell, K. (1986). Constraints on the development of coordination. In M.G. Wade & H.T. A. Whiting (Eds.), *Motor development in children: Aspects of coordination and control* (pp. 341-360). Dordect, The Netherlands: Nihjoff. http://dx.doi.org/10.1007/978-94-009-4460-2_19.

NICHD Early Child Care Research Network. (2005). Pathways to reading: The role of oral language in the transition to reading. *Developmental Psychology*, *41*(2), 428-442. https://doi.org/10.1037/0012-1649.41.2.428.

Nittrouer, S., Antonelli, J., & Lowenstein, J. H. (2022). The emergence of bifurcated structure in children's language. *Journal of Experimental Psychology: General*. *151*(12), 3045–3059. https://doi.org/10.1037/xge0001245

Nittrouer, S., Caldwell-Tarr, A., Low, K. E., & Lowenstein, J. H. (2017). Verbal working memory in children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *60*(11), 3342-3364. https://doi.org/10.1044/2017_JSLHR-H-16-0474.

Nittrouer, S., Muir, M., Tietgens, K., Moberly, A. C., & Lowenstein, J. H. (2018). Development of phonological, lexical, and syntactic abilities in children with cochlear implants across the elementary grades. *Journal of Speech, Language, and Hearing Research*, *61*(10), 2561-2577. https://doi.org/10.1044/2018_JSLHR-H-18-0047.

Oppici, L., Rudd, J. R., Buszard, T., & Spittle, S. (2020). Efficacy of a 7-week dance (RCT) PE curriculum with different teaching pedagogies and levels of cognitive challenge to improve working memory capacity and motor competence in 8–10 years old children. *Psychology of Sport and Exercise*, *50*, 101675. https://doi.org/10.1016/j.psychsport.2020.101675.

Özçalişkan, Ş., Adamson, L. B., Dimitrova, N., Bailey, J., & Schmuck, L. (2016). Baby sign but not spontaneous gesture predicts later vocabulary in children with Down Syndrome. *Journal of Child Language*, *43*(4), 948-963. https://doi.org/10.1017/S030500091500029X

Özçalışkan, Ş., Adamson, L. B., Dimitrova, N., & Baumann, S. (2017). Early gesture provides a helping hand to spoken vocabulary development for children with autism, down syndrome, and typical development. *Journal of Cognition and Development*, *18*(3), 325-337. https://doi.org/10.1080/15248372.2017.1329735.

Park, J., Ellis Weismer, S., & Kaushanskaya, M. (2018). Changes in executive function over time in bilingual and monolingual school-aged children. Developmental Psychology, 54(10), 1842-1853. https://doi.org/10.1037/dev0000562.

Pearson Education, Inc. (2018, October 16). PPVT-5 and EVT-3 Technical Summary. Bloomington, MN.

Pexman, P. M., Holyk, G. G., & Monfils, M. H. (2003). Number of-features effects and semantic processing. *Memory & Cognition, 32*, 842–855. https://doi.org/10.3758/bf03196439.

Phillips, B. M., Kim, Y. S. G., Lonigan, C. J., Connor, C. M., Clancy, J., & Al Otaiba, S. (2021). Supporting language and literacy development with intensive small-group interventions: An early childhood efficacy study. *Early Childhood Research Quarterly*, *57*, 75-88. https://doi.org/10.1016/j.ecresq.2021.05.004.

Philp, J., & Duchesne, S. (2016). Exploring engagement in tasks in the language classroom. *Annual Review of Applied Linguistics*, *36*, 50-72. https://doi.org/10.1017/S0267190515000094.

Pisoni, D., Kronenberger, W., Roman, A., & Geers, A. (2011). Article 7: Measures of digit span and verbal rehearsal speed in deaf children following more than 10 years of cochlear implantation. *Ear and Hearing*, *32*(1), 60s-74s. https://doi.org/10.1097/AUD.0b013e3181ffd58e.

Pruden, S. M., Hirsh-Pasek, K., Golinkoff, R. M., & Hennon, E. A. (2006). The birth of words: Ten-month-olds learn words through perceptual salience. *Child development*, *77*(2), 266-280. https://doi.org/10.1111/j.1467-8624.2006.00869.x.

Pruitt, M., & Morini, G. (2021). Examining the role of physical activity on word learning in school-aged children. *Journal of Speech, Language, and Hearing Research*, *64*(5), 1712-1725. https://doi.org/10.1044/2021_JSLHR-20-00359.

Redmond, S. M. (2002). The use of rating scales with children who have language impairments: A tutorial. *American Journal of Speech-Language Pathology, 11*, 124–138. https://doi.org/10.1044/1058-0360(2002/013).

Redmond, S. M. (2020). Clinical intersections among idiopathic language disorder, Social (Pragmatic) Communication Disorder, and Attention-Deficit/Hyperactivity Disorder. *Journal of Speech, Language, and Hearing Research, 63(10),* 3263-3276. https://doi.org/10.1044/2020_JSLHR-20-00050.

Redmond, S. M., & Ash, A. C. (2014). A cross-etiology comparison of the socioemotional behavioral profiles associated with attention-deficit/hyperactivity disorder and specific language impairment. *Clinical Linguistics & Phonetics, 28,* 346–365. https://doi.org/10.3109/02699206.2013.868518.

Redmond, S. M., Hannig, K. M., & Wilder, A. (2019). Redmond (2002) Revisited: Have standardized behavioral rating scales gotten better at accommodating for overlapping symptoms with language impairment?. In *Seminars in speech and language* (Vol. 40, No. 04, pp. 272-290). Thieme Medical Publishers. https://doi.org/10.1055/s-0039-1692963.

Reinders, N. J., Bryden, P. J., & Fletcher, P. C. (2019). 'Dance is something that anyone can do': Creating dance programs for all abilities. *Research in Dance Education*, *20*(2), 257-274. https://doi.org/10.1080/14647893.2019.1584175.

Reinders, N., Bryden, P. J., & Fletcher, P. C. (2015). Dancing with Down syndrome: a phenomenological case study. *Research in Dance Education*, *16*(3), 291-307. https://doi.org/10.1080/14647893.2015.1036018

Rimmer, J. (2008, June/July). Promoting inclusive physical activity communities for people with disabilities. *President's Council on Physical Fitness and Sports Research Digest, 9*(2), 1-8.

Rimmer, J. H., & Marques, A. C. (2012). Physical activity for people with disabilities. *The Lancet*, *380*(9838), 193-195. https://doi.org/10.1016/S0140-6736(12)61028-9.

Rimmer, J. H., Riley, B., Wang, E., Rauworth, A., & Jurkowski, J. (2004). Physical activity participation among persons with disabilities: barriers and facilitators. *American Journal of Preventive Medicine*, *26*(5), 419-425. https://doi.org/10.1016/j.amepre.2004.02.002.

Ritter, N., Kilinc, E., Navruz, B., & Bae, Y. (2011). Test Review: L. Brown, RJ Sherbenou, & SK Johnsen Test of Nonverbal Intelligence-4 (TONI-4). Austin, TX: PRO-ED, 2010. *Journal of Psychoeducational Assessment*, *29*(5), 484-488. https://doi.org/10.1177/0734282911400400.

Rogers, D. C., Dittner, A. J., Rimes, K. A., & Chalder, T. (2017). Fatigue in an adult attention deficit hyperactivity disorder population: A trans-diagnostic approach. *British Journal of Clinical Psychology*, *56*(1), 33-52. https://doi.org/10.1111/bjc.12119.

Rowe, J., Lavender, A., & Turk, V. (2006). Cognitive executive function in Down's syndrome. *British Journal of Clinical Psychology, 45*(1), 5-17. https://doi.org/10.1348/014466505X29594.

Rubin, I.L. & Crocker, A.C. (1989). *Developmental disabilities: Delivery of medical care for children and adults.* Lea & Febiger.

Rudd, J., Buszard, T., Spittle, S., O'Callaghan, L., & Oppici, L. (2021). Comparing the efficacy (RCT) of learning a dance choreography and practicing creative dance on improving executive functions and motor competence in 6–7 years old children. *Psychology of Sport and Exercise*, *53*, 101846. https://doi.org/10.1016/j.psychsport.2020.101846.

Sáez-Francàs, N., Alegre, J., Calvo, N., Ramos-Quiroga, J. A., Ruiz, E., Hernández-Vara, J., & Casas, M. (2012). Attention-deficit hyperactivity disorder in chronic fatigue syndrome patients. *Psychiatry Research*, *200*(2-3), 748-753. https://doi.org/10.1016/j.psychres.2012.04.041.

Samuels, W. E., Tournaki, N., Blackman, S., & Zilinski, C. (2016). Executive functioning predicts academic achievement in middle school: A four-year longitudinal study. *The Journal of Educational Research*, *109*(5), 478-490. https://doi.org/10.1080/00220671.2014.979913.

Samuelson, L. K., Kucker, S. C., & Spencer, J. P. (2017). Moving word learning to a novel space: A dynamic systems view of referent selection and retention. *Cognitive Science, 41*, 52-72. https://doi.org/10.1111/cogs.12369.

Sarant, J. Z., Harris, D. C., & Bennet, L. A. (2015). Academic outcomes for school-aged children with severe–profound hearing loss and early unilateral and bilateral cochlear implants. *Journal of Speech, Language, and Hearing Research*, *58*(3), 1017-1032. https://doi.org/10.1044/2015_JSLHR-H-14-0075.

Schmidt, M., Egger, F., & Conzelmann, A. (2015). Delayed positive effects of an acute bout of coordinative exercise on children's attention. *Perceptual and Motor Skills*, *121*(2), 431-446. https://doi.org/10.2466/22.06.PMS.121c22x1.

Schneider, J. L., & Iverson, J. M. (2022). Cascades in action: How the transition to walking shapes caregiver communication during everyday interactions. *Developmental psychology*, *58*(1), 1-16. https://doi.org/10.1037/dev0001280.

Schneider, J. L., Roemer, E. J., Northrup, J. B., & Iverson, J. M. (2023). Dynamics of the dyad: How mothers and infants co-construct interaction spaces during object play. *Developmental science*, *26*(2), e13281. https://doi.org/10.1111/desc.13281.

Schuele, C. M., & Boudreau, D. (2008). Phonological awareness intervention: Beyond the basics. *Language, Speech, and Hearing Services in the Schools, 39*(1), 3-20. https://doi.org/10.1044/0161-1461(2008/002).

Shao, X., Tan, L. H., & He, L. (2022). Physical activity and exercise alter cognitive abilities, and brain structure and activity in obese children. *Frontiers in Neuroscience, 16*, 1019129. https://doi.org/10.3389/fnins.2022.1019129.

Shen, Y., Zhao, Q., Huang, Y., Liu, G., & Fang, L. (2020). Promotion of street-dance training on the executive function in preschool children. *Frontiers in Psychology*, 2817. https://doi.org/10.3389/fpsyg.2020.585598.

Shields, N., Dodd, K. J., & Abblitt, C. (2009). Do children with Down syndrome perform sufficient physical activity to maintain good health? A pilot study. *Adapted Physical Activity Quarterly*, *26*(4), 307-320. https://doi.org/10.1123/apaq.26.4.307.

Shields, R. H., Kaat, A. J., McKenzie, F. J., Drayton, A., Sansone, S. M., Coleman, J., ... & Hessl, D. (2020). Validation of the NIH toolbox cognitive battery in intellectual disability. Neurology, 94(12), e1229-e1240. https://doi.org/10.1212/WNL.0000000000009131.

Siakaluk, P. D., Pexman, P. M., Sears, C. R., Wilson, K., Locheed, K., & Owen, W. J. (2008). The benefits of sensorimotor knowledge: Body-object interaction facilitates semantic processing. *Cognitive Science, 32*, 591–605. https://doi.org/10.1080/03640210802035399.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: a meta-analysis. *Pediatric exercise science*, *15*(3), 243-256. https://doi.org/10.1123/pes.15.3.243.

Sikora, K., Roelofs, A., Hermans, D., & Knoors, H. (2019). Executive control in language production by children with and without language impairment. *International Journal of Language & Communication Disorders*, *54*(4), 645-655. https://doi.org/10.1111/1460-6984.12470.

Smith, E., Hokstad, S., & Næss, K. A. B. (2020). Children with Down syndrome can benefit from language interventions; Results from a systematic review and meta-analysis. *Journal of Communication Disorders*, *85*. https://doi.org/10.1016/j.jcomdis.2020.105992.

Smith, E., Næss, K. A. B., & Jarrold, C. (2017). Assessing pragmatic communication in children with Down syndrome. *Journal of Communication Disorders*, *68*, 10-23. https://doi.org/10.1016/j.jcomdis.2017.06.003.

Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in cognitive sciences*, *7*(8), 343-348. https://doi.org/10.1016/S1364-6613(03)00156-6.

Snowling, M. J., & Hulme, C. (2012). Interventions for children's language and literacy difficulties. *International Journal of Language & Communication Disorders*, *47*(1), 27-34. https://doi.org/10.1111/j.1460-6984.2011.00081.x.

Sokolov, M., Gordon, K. A., Polonenko, M., Blaser, S. I., Papsin, B. C., & Cushing, S. L. (2019). Vestibular and balance function is often impaired in children with profound unilateral sensorineural hearing loss. *Hearing Research, 372*, 52-61. https://doi.org/10.1016/j.heares.2018.03.032.

Soltani, A., Schworer, E. K., & Esbensen, A. J. (2022). Executive functioning and verbal fluency performance in youth with Down syndrome. *Research in developmental disabilities*, *131*, 104358. https://doi.org/10.1016/j.ridd.2022.104358.

Stevenson, J., McCann, D., Watkin, P., Worsfold, S., Kennedy, C., & Hearing Outcomes Study Team. (2010). The relationship between language development and behaviour problems in children with hearing loss. *Journal of Child Psychology and Psychiatry*, *51*(1), 77-83. https://doi.org/10.1111/j.1469-7610.2009.02124.x.

Stewart, D. A., & Ellis, M. K. (2005). Sports and the deaf child. *American Annals of the Deaf*, *150*(1), 59-66. http://www.jstor.org/stable/26234702.

Subramanian, S. K., Sharma, V. K., Arunachalam, V., Radhakrishnan, K., & Ramamurthy, S. (2015). Effect of structured and unstructured physical activity training on cognitive functions in adolescents–a randomized control trial. *Journal of clinical and diagnostic research: JCDR*, *9*(11), CC04-CC9. https://doi.org/10.7860/JCDR/2015/14881.6818.

Sutherland, K. S., & Morgan, P. L. (2003). Implications of transactional processes in classrooms for students with emotional/behavioral disorders. *Preventing School Failure: Alternative Education for Children and Youth, 48*(1), 32–37. https://doi.org/10.1080/1045988X.2003.10871077.

Takahashi, H., An, M., Matsumura, T., Seki, M., Ogawa, Y., Sasai, T., ... & Kato, T. (2023). Effectiveness of dance/movement therapy intervention for children with intellectual disability at an early childhood special education preschool. *American Journal of Dance Therapy*, *45*(1), 20-40. https://doi.org/10.1007/s10465-022-09356-3.

Ten Eycke, K. D., & Dewey, D. (2016). Parent-report and performance-based measures of executive function assess different constructs. *Child Neuropsychology*, *22*(8), 889-906. https://doi.org/10.1080/09297049.2015.1065961.

Thelen, E. (2005). Dynamic systems theory and the complexity of change. *Psychoanalytic Dialogues, 15*, 255–283. https://doi.org/10.1080/10481881509348831.

Theunissen, S. C., Rieffe, C., Kouwenberg, M., De Raeve, L. J., Soede, W., Briaire, J. J., & Frijns, J. H. (2014a). Behavioral problems in school-aged hearing-impaired children: the influence of sociodemographic, linguistic, and medical factors. *European Child & Adolescent Psychiatry*, *23*(4), 187-196. https://doi.org/10.1007/s00787-013-0444-4.

Theunissen, S. C., Rieffe, C., Netten, A. P., Briaire, J. J., Soede, W., Schoones, J. W., & Frijns, J. H. (2014b). Psychopathology and its risk and protective factors in hearing-impaired children and adolescents: A systematic review. *JAMA Pediatrics*, *168*(2), 170-177. https://doi.org/10.1001/jamapediatrics.2013.3974.

Tine, M. T., & Butler, A. G. (2012). Acute aerobic exercise impacts selective attention: An exceptional boost in lower-income children. *Educational Psychology*, *32*(7), 821-834. https://doi.org/10.1080/01443410.2012.723612.

Tirosh, E., & Cohen, A. (1998). Language deficit with attention deficit disorder: A prevalent comorbidity. *Journal of Child Neurology, 13*, 493–497. https://doi.org/10.1177/088307389801301005.

Tomas, E., & Vissers, C. (2019). Behind the scenes of developmental language disorder: Time to call neuropsychology back on stage. *Frontiers in Human Neuroscience*, *12*, 517. https://doi.org/10.3389/fnhum.2018.00517.

Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and hearing*, *36*(0 1), 76S. https://doi.org/10.1097%2FAUD.0000000000000219.

Tomblin, J. B., Oleson, J., Ambrose, S. E., Walker, E. A., McCreery, R. W., & Moeller, M. P. (2020). Aided hearing moderates the academic outcomes of children with mild to severe hearing loss. *Ear and Hearing*, *41*(4), 775-789. https://doi.org/10.1097/AUD.0000000000000823.

Toumpaniari, K., Loyens, S., Mavilidi, M. F., & Paas, F. (2015). Preschool children's foreign language vocabulary learning by embodying words through physical activity and gesturing. *Educational Psychology Review*, *27*, 445-456. https://doi.org/10.1007/s10648-015-9316-4.

Tungate, A. S., & Conners, F. A. (2021). Executive function in Down syndrome: A meta-analysis. *Research in Developmental Disabilities*, *108*. https://doi.org/10.1016/j.ridd.2020.103802

Vandoni, M., Giuriato, M., Pirazzi, A., Zanelli, S., Gaboardi, F., Carnevale Pellino, V., ... & Calcaterra, V. (2023). Motor Skills and Executive Functions in Pediatric Patients with Down Syndrome: A Challenge for Tailoring Physical Activity Interventions. *Pediatric Reports*, *15*(4), 691-706. https://doi.org/10.3390/pediatric15040062

Van Geert, P. (2000). The dynamics of general developmental mechanisms: From Piaget and Vygotsky to dynamic systems models. *Current Directions in Psychological Science*, *9*(2), 64-68. https://doi.org/10.1111/1467-8721.00062.

Varni, J.W. (1998). PedsQL 3.0, Multidimensional Fatigue Scale [Measurement instrument]. College Station, TX.

Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., ... & Blumberg, S. J. (2014). Trends in the parent-report of health care provider-diagnosed and medicated attention-deficit/hyperactivity disorder: United States, 2003–

2011. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(1), 34-46. https://doi.org/10.1016/j.jaac.2013.09.001.

Vitiello, V., & Williford, A. P. (2016). Relations between social skills and language and literacy outcomes among disruptive preschoolers: Task engagement as a mediator. *Early Childhood Research Quarterly*, *36*, 136-144. https://doi.org/10.1016/j.ecresq.2015.12.011.

Vitrikas, K., Dalton, H., & Breish, D. (2020). Cerebral palsy: an overview. *American family physician*, *101*(4), 213-220.

Vriezen, E. R., & Pigott, S. E. (2002). The relationship between parental report on the BRIEF and performance-based measures of executive function in children with moderate to severe traumatic brain injury. *Child Neuropsychology*, *8*(4), 296-303. https://doi.org/10.1076/chin.8.4.296.13505.

Walle, E. A., & Campos, J. J. (2014). Infant language development is related to the acquisition of walking. *Developmental psychology*, *50*(2), 336-348. https://doi.org/10.1037/a0033238.

Warren, S. F., Fey, M. E., Finestack, L. H., Brady, N. C., Bredin-Oja, S. L., & Fleming, K. K. (2008). A randomized trial of longitudinal effects of low-intensity responsivity education/prelinguistic milieu teaching. *Journal of Speech Language and Hearing Research, 51*, 451–470. https://doi.org/10.1044/1092-4388(2008/033)

Weiland, C., Barata, M. C., & Yoshikawa, H. (2014). The co-occurring development of executive function skills and receptive vocabulary in preschool-aged children: A look at the direction of developmental pathways. *Infant and Child Development, 23*(1), 4–21. https://doi.org/10.1002/icd.1829.

Werfel, K. L. (2017). Emergent literacy skills in preschool children with hearing loss who use spoken language: Initial findings from the early language and literacy acquisition (ELLA) study. *Language, Speech, and Hearing Services in Schools*, *48*(4), 249-259. https://doi.org/10.1044/2017_LSHSS-17-0023.

Werfel, K. L., & Hendricks, A. E. (2016). The relation between child versus parent report of chronic fatigue and language/literacy skills in school-age children with cochlear implants. *Ear and Hearing*, *37*(2), 216-224. https://doi.org/10.1097/AUD.0000000000000242.

Werfel, K. L., & Lund, E. A. (2024). Effects of Integrating Different Types of Physical Activity Into Virtual Rapid Word Learning Instruction for Children Who Are Deaf and Hard of Hearing. *Topics in Language Disorders*, *44*(2), 96-110. https://doi.org/10.1097/TLD.0000000000000338

Werfel, K. L., Lund, E., & Schuele, C. M. (2015). Print knowledge of preschool children with hearing loss. *Communication Disorders Quarterly, 36*(2), 107-111. https://doi.org/10.1177/1525740114539002.

Werfel, K. L., Reynolds, G., Hudgins, S., Castaldo, M., & Lund, E. A. (2021). The production of complex syntax in spontaneous language by 4-year-old children with hearing loss. *American Journal of Speech-Language Pathology*, *30*(2), 609-621. https://doi.org/10.1044/2020_AJSLP-20-00178.

West, K. L., & Iverson, J. M. (2021). Communication changes when infants begin to walk. *Developmental science*, *24*(5), e13102. https://doi.org/10.1111/desc.13102.

Wiig, E. H., Semel, E., & Secord, W. A. (2013b). Clinical evaluation of language fundamentals (5th ed.). [Measurement instrument]. Bloomington: NCS Pearson.

Wolraich, M. L., Hagan, J. F., Allan, C., Chan, E., Davison, D., Earls, M., ... & Zurhellen, W. (2019). Clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Pediatrics*, *144*(4). https://doi.org/10.1542/peds.2019-2528.

Wolraich, M. L., Lambert, E. W., Bickman, L., Simmons, T., Doffing, M. A., & Worley, K. A. (2004). Assessing the impact of parent and teacher agreement on diagnosing attention-deficit hyperactivity disorder. *Journal of Developmental & Behavioral Pediatrics*, *25*(1), 41-47. https://dx.doi.org/10.1097/00004703-200402000-00007.

Woodard, K., Pozzan, L., & Trueswell, J. C. (2016). Taking your own path: Individual differences in executive function and language processing skills in child learners. *Journal of Experimental Child Psychology*, *141*, 187-209. https://doi.org/10.1016/j.jecp.2015.08.005.

Woods, R. J., & Wilcox, T. (2013). Posture support improves object individuation in infants. *Developmental Psychology*, *49*(8), 1413-1424. https://doi.org/10.1037/a0030344.

Xu, W., Li, C., & Wang, L. (2020). Physical activity of children and adolescents with hearing impairments: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(12), 4575. https://doi.org/10.3390/ijerph17124575.

Yew, S. G. K., & O'Kearney, R. (2013). Emotional and behavioural outcomes later in childhood and adolescence for children with specific language impairments: Meta-analyses of controlled prospective studies. *Journal of Child Psychology and Psychiatry*, *54*, 516–524. https://doi.org/10.1111/jcpp.12009.

Yoder, P., Woynaroski, T., Fey, M., & Warren, S. (2014). Effects of dose frequency of early communication intervention in young children with and without Down syndrome. *American Journal on Intellectual and Developmental Disabilities*, *119*(1), 17-32. https://doi.org/10.1352/1944-7558-119.1.17.

Zach, S., Inglis, V., Fox, O., Berger, I., & Stahl, A. (2015). The effect of physical activity on spatial perception and attention in early childhood. *Cognitive Development*, *36*, 31-39. https://doi.org/10.1016/j.cogdev.2015.08.003.

Zampini, L., & D'Odorico, L. (2013). Vocabulary development in children with Down syndrome: Longitudinal and cross-sectional data. *Journal of Intellectual and Developmental Disability*, *38*(4), 310-317. https://doi.org/10.3109/13668250.2013.828833.

Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P., & Gao, Z. (2017). Effects of physical activity on motor skills and cognitive development in early childhood: a systematic review. *BioMed research international*, *2017*. https://doi.org/10.1155/2017/2760716.

Zhang, Z. (2022). Learner engagement and language learning: a narrative inquiry of a successful language learner. *The Language Learning Journal*, *50*(3), 378-392. https://doi.org/10.1080/09571736.2020.1786712.

APPENDICES

Appendix A

Engagement Scales

Rating Scale	Description
1	Extremely engaged; always imitates words/phrases when appropriate, always imitates movements, no redirecting to activity, independently stays in assigned spot.
2	Very engaged; often imitates words/phrases when appropriate, often imitates movements, needs a few reminders to redirect attention to activity, independently stays in assigned spot.
3	Somewhat engaged; inconsistently imitates words/phrases when appropriate, inconsistently imitates movements, some redirecting to the activity, some fidgeting, some inappropriate dialogue during activity, independently stays in assigned spot.
4	Slightly engaged; never imitates words/phrases when appropriate, rarely imitates movements, needs constant redirecting to the activity, fidgeting, constantly talking with others while activity is continuing, inconsistently stays in assigned spot.
5	Not at all engaged; never imitates words/phrases when appropriate, never imitates movements, even with constant redirection to the activity does not attend, fidgeting, constantly talking with others while the activity is occurring, unable to stay in assigned spot.

Engagement Rating Scale: Dance Session

Time Off Task Formula

Total Time of Video – Time- Off Task = Total Amount of Time on Task

Dance: ____-_____=____

Rating Scale	Description
1	Extremely engaged; always comments when appropriate, no redirecting to activity, maintains eye contact with activity without prompting, independently sits.
2	Very engaged; often comments when appropriate, needs a few reminders to redirect attention to activity, maintains eye contact with activity with minor redirection, independently sits.
3	Somewhat engaged; inconsistently comments when appropriate, some redirecting to the activity, inconsistent eye contact with activity, some fidgeting, some inappropriate dialogue during activity, independently sits.
4	Slightly engaged; never comments when appropriate, needs constant redirecting to activity, does not maintain eye contact with activity, fidgeting, constantly talking with others while activity is continuing, inconsistently sits.
5	Not at all engaged; never comments when appropriate, even with constant redirection to activity does not attend, does not maintain eye contact with activity, fidgeting, constantly talking while the activity is occurring, unable to sit independently.

Engagement Rating Scale: Traditional Session

Time Off Task Formula

Total Time of Video – Time- Off Task = Total Amount of Time on Task

Traditional: ____-_____=____

Appendix B

Sample Dance Intervention Lesson

Sessions 1-6

Set-up

- Materials: music and speaker, props, and lesson words for the day
- Students sit in a semi-circle around SLP (in assigned spots on the carpet); all having view of SLP
- Music volume is appropriate to easily hear SLP

Targeted Words: butterfly, snail, toes, fly, kiss, hide, climb, reach, top, below

Transition: "Hello Song" to sit on carpet

Exercise 1

- Movements: butterfly position with legs, flap knees to "fly", going over to "kiss" your toes; straighten legs out to front, point and flex feet; round body like a snail in a shell
- Words: butterfly, fly, kiss, toes, hide, snail
- Instructions: SLP will have students follow along as she models movements
    - Target "butterfly" and "fly"
        - SLP: "Sit like a butterfly;" "What are you?" [pause for response] "A butterfly!"
        - SLP: "Alright butterflies, let's fly!" [demonstrate flapping knees to fly]
        - All: "Fly!" [as we flap knees]
        - SLP: "Okay butterflies, time to rest." [demonstrate stop and rest]
        - Repeat 5x
    - Target "kiss" and "toes"
        - SLP: "What are these?" [point to toes; wait for response] "Toes!"
        - SLP: "Let's give our toes a kiss!" [muah!]
        - SLP: "Ready? 1-2-3.."
        - All: "Kiss!" [kiss toes while in butterfly]
        - [come back up] "Eww! My toes are stinky!"
        - Repeat 5x
        - SLP: "Straighten your legs. Where did our toes go? There they are! Let's tell them "hello toes!" [flex feet]
        - All: "Hello toes!"
        - SLP: "Let's tell them goodbye toes!" [point toes]
        - All: "Goodbye toes!"
        - Repeat 5x
    - Target "hide" and "snail"

- SLP: “Let’s be snails!” [brings knees to chest] “What are we?”
- All: “Snails!”
- SLP: “Snails go in their shells to hide.” [demonstrate rounding body into ball]
- SLP: “Ready? 1-2-3..”
- All: “Hide!” “[round body into ball]
- SLP: “Time to come out!” [demonstrate legs and arms coming outwards]
- SLP: “Ready, 1-2-3…”
- All: [legs and arms come outwards]
- Repeat 5x

VITA

Jessica Mattingly, M.S., CCC-SLP
j.mattingly@tcu.edu
615-692-4230

EDUCATION

In Progress **Ph.D. in Health Sciences** *[3-year accelerated program]*

Texas Christian University in Fort Worth, TX
Anticipated graduation date is in May 2024
Project 1: "Parent reported ADHD-linked behaviors, fatigue, and language in children who are deaf and hard of hearing" *(published)*
Project 2: "Effects of dance on word learning in preschool children with Down Syndrome" *(manuscript submitted)*
Project 3: "The Impact of Physical Activity on the Language and Executive Functioning of Children with Special Needs" *(manuscript in preparation)*

2012 **Master of Science in Speech-Language Pathology**

Vanderbilt University in Nashville, TN
Thesis: **"**Receptive Vocabulary in Preschool-Aged Children Who Stutter"
Advisors: Edward Conture, Ph.D., Ellen Kelly, Ph.D., and Stephen Camarata, Ph.D.

2010 **Bachelor of Arts in Speech Pathology and Audiology**
Calvin University in Grand Rapids, Michigan
Honors Thesis: "Hemispheric Specialization in Processing Idioms"
Advisors: Judith Vander Woude, Ph.D. and Paul Moes, Ph.D.

PROFESSIONAL CERTIFICATION AND MEMBERSHIP

Certificate of Clinical Competence, American Speech-Language Hearing Association
State Licensures in California, Hawaii, Kentucky, Nevada, Texas, and Virginia
Membership, Society for Research in Child Development
Membership, American Dance Therapy Association

PUBLICATIONS

Mattingly, J., Werfel, K. L., & Lund, E. (2023). Parent-Reported Attention-Deficit/Hyperactivity Disorder–Linked Behaviors, Fatigue, and Language in Children Who Are Deaf and Hard of Hearing. *Perspectives of the ASHA Special Interest Groups*, 1-13.

Mattingly, J., Trevino, C., & Lund, E., (2023). Dance and the executive functioning skills of children: a scoping review. Featured in Bryl, K., Fontanesi, C., & Stewart, C. (2023). Abstracts from the 2022 Research and Thesis Poster Session of the 57th Annual

American Dance Therapy Association Conference, Renewed Connections: Dance/Movement Therapy Fostering Community Healing, October 27–30, 2022. American Journal of Dance Therapy, 45, 109-121.

PRESENTATIONS

"Effects of Dance on Word Learning in Preschool Children with Down Syndrome"
First author: Jessica Mattingly, M.S.
Co-authors: Lynita Yarbrough, M.S. and Emily Lund, Ph.D.
Poster presented at the Annual Convention of the American Speech-Language Hearing Association, Boston, MA, in November 2023

"Word-learning and movement"
Invited oral presentation at the Harris College Faculty Research Symposium, Fort Worth, TX, in September 2023

"Effects of dance on word learning in preschool children with Down Syndrome"
First author: Jessica Mattingly, M.S.
Co-authors: Lynita Yarbrough, M.S., and Emily Lund, Ph.D.
Poster presented at the Harris College Student Research Conference, Fort Worth, TX, in April 2023 and the Texas Christian University Research and Creative Activities Week Poster Session, Fort Worth, TX, in September 2023

"Dance and word learning in preschool children with Down Syndrome: Study design"
Invited oral presentation at the Harris College Faculty Research Symposium, Fort Worth, TX, in September 2022

"ADHD and Hearing Loss: Is it really inattention?
First author: Jessica Mattingly, M.S.
Co-authors: Emily Lund, Ph.D. and Krystal Werfel, Ph.D.
Oral seminar (1 hour) presented at the Annual Convention of the American Speech-Language Hearing Association, New Orleans, LA, in November 2022

"Dance and the executive functioning skills of children: a scoping review."
First author: Jessica Mattingly
Co-authors: Courtney Trevino, M.S., and Emily Lund, Ph.D.
Poster presented at the Annual Conference of the American Dance Therapy Association, Montreal, Canada, in October 2022

"Parent and teacher report of ADHD in children with hearing loss: Is there a tendency towards over-reporting?"
First author: Jessica Mattingly
Co-authors: Krystal Werfel, Ph.D. and Emily Lund, Ph.D.
Poster presented at the Symposium on Research in Child Language Disorders, Madison, WI, in June 2022 and the Harris College of Nursing and Health Sciences Student Research Symposium, Fort Worth, TX, in April 2022

“Receptive Vocabulary in Preschool-Aged Children Who Stutter”
First author: Jessica Mattingly
Co-authors: Edward Conture, Ph.D. and Ellen Kelly, Ph.D.
Poster presented at the Annual Convention of the American Speech-Language Hearing Association, Chicago, IL, in November 2012

“Social Communication Training and Vocational Rehabilitation for Adults with ASD”
First author: Jessica Mattingly
Co-Authors: Julia Low, M.S., Martine McKenzie McGroarty, M.S., and Jennifer Hall, M.S.
Poster presented at the Annual Convention of the American Speech-Language Hearing Association, San Diego, CA, in November 2011

“Hemispheric Specialization in Processing Idioms”
First author: Jessica Mattingly
Co-Authors: Tory Larsen, Judith Vander Woude, Ph.D. and Paul Moes, Ph.D.
Poster presented at the Annual Convention of the American Speech-Language Hearing Association, Philadelphia, PA, in November 2010

COURSES TAUGHT

January 2023-May 2023	Anatomy and Physiology of the Speech and Hearing Mechanism: *Instructor of record*
August 2022-December 2022	Phonetics: *Instructor of record*
January 2022-May 2022	Anatomy and Physiology of the Speech and Hearing Mechanism: *Teaching assistant*

CLINICAL AND RESEARCH EXPERIENCE

August 2021-present	Research Assistant, *Texas Christian University* Child Hearing, Language, Literacy and Deafness Lab *Primary Investigator: Emily Lund* Conduct and support research activities such as writing/reporting and data collection and analysis
August 2021-present	Digital Speech-Language Pathologist, *Private Contractor* Provide evaluations and treatment via teletherapy
July 2019-May 2021	Digital Therapist and Trainer, *Amplio Learning* Provided evaluations and treatment via teletherapy for schools

Trained incoming speech-language pathologists

Trained teachers on use of virtual dyslexia curriculum

January 2017-May 2021 Travel Speech-Language Pathologist

Provided evaluations, treatment, and caregiver training
Supervised speech-language pathology assistants

April 2015-April 2017 Speech-Language Pathologist, *My Left Foot Pediatric Therapy*

Provided evaluations and treatment for pediatric and adult patients

Provided in-services and consultation for assessment and use of augmentative and alternative communication

August 2012-March 2015 Speech-Language Pathologist, *Bright Beginnings*

Provided evaluations and treatment for students and clients

Developed a reading clinic program as reading clinic coordinator

Acted as AAC consultant guiding evaluations for the clinic

Supervised speech-language pathology assistants

HONORS AND AWARDS

Three Minute Thesis First Place Winner, Harris College of Nursing and Health Sciences, Texas Christian University, 2024

Student Research Grant, Davies School of Communication Disorders, Texas Christian University, 2023

Student and Early Career Council (SECC) Dissertation Funding Award (applied; not funded), Society for Research in Child Development, 2023

F31 Predoctoral Individual National Research Service Award (applied; not funded), National Institutes of Health, 2022

Exploring your PhD Options panelist, Minority Student Leadership Program, American Speech Language Hearing Association, 2022

NIH Student Travel Award, Symposium on Research in Child Language Disorders, 2022

Student International Travel Grant, Office of Graduate Studies, Texas Christian University, 2022

Student Conference Grant, Harris College of Nursing and Health Sciences, Texas Christian University, 2022 and 2023

Student Research Grant in Early Childhood Language Development (applied; not awarded), ASHFoundation, 2022

Student Research Grant (applied; not awarded), Texas Speech Language Hearing Foundation, 2022

Stipends to Attract Remarkable Students of Diversity Fellowship Award, Texas Christian University, 2021, 2022, and 2023

Student Research Grant, Harris College of Nursing and Health Sciences, Texas Christian University, 2021, 2022, and 2023

Harris College Graduate Cabinet, Harris College of Nursing and Health Sciences, Texas Christian University, 2021-2023

Harris College Student-Faculty Liaison, Harris College of Nursing and Health Sciences, Texas Christian University, 2022-2023

Enhancing the Preparation of Speech-Language Pathologists to Collaboratively Address the Language and Literacy Needs of Children with Disabilities Training Grant, US Department of Education and Vanderbilt University, 2010-2012

Fundraising Chair, NSSLHA Vanderbilt University Chapter, 2011-2012

Awardee, Minority Student Leadership Program, American Speech-Language-Hearing Association, 2010

Awardee, Promoting the Next Generation of Researchers, American Speech-Language-Hearing Association, 2010

Student Representative, Master's Program Planning Committee, Calvin College, 2010

President, NSSLHA Calvin College Chapter, 2009-2010

Awardee, David J. Holquist Scholarship, Calvin College, 2009

Research Fellow, McGregor Fellowship Undergraduate Research Program, Calvin College, 2009

Vice-President, NSSLHA Calvin College Chapter, 2008-2009

Invited Board Member, NSSLHA Calvin College Chapter, 2007-2008

Awardee, National Merit Scholar, 2006

Awardee, Communications Student of the Year, Owensboro Community College (received as a high school senior dual-enrolled), 2006